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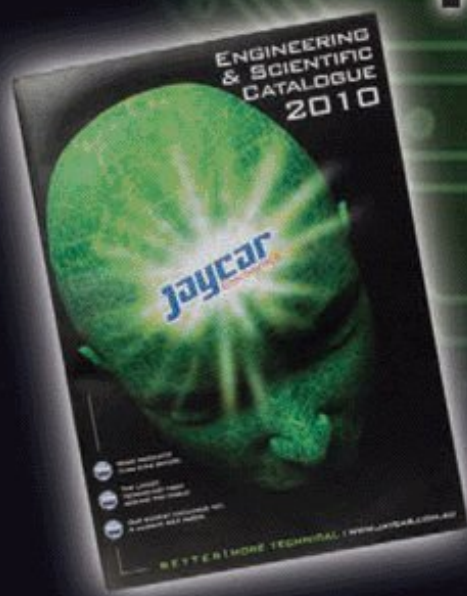
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BATTERY ZAPPER KIT - MKII

KC-5479 \$46.50

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Prolongs the life of your lead-acid batteries. Like the original 2005 project, this circuit produces short high-level bursts of energy to reverse the sulphation effect. The battery condition checker is no longer included and the circuit has been updated and revamped to provide more reliable, long-term operation. Not recommended for use with gel batteries

- PCB with solder mask & overlay components
- Screen printed machined case
- 6, 12 & 24VDC



FUEL / AIR MIXTURE DISPLAY KIT

KC-5485 \$35.00 plus postage & packing

Displays your car's air-fuel ratio as you drive. Designed to monitor a wideband oxygen sensor and its associated wideband controller. Alternatively it can be used to monitor a narrowband oxygen sensor or for monitoring other types of engine sensors.

- 12VDC
- Double-sided plated PCB
- Programmed PIC
- Electronic components
- Case with machined and screen printed lid



SD CARD SPEECH RECORDER & PLAYER KIT

KC-5481 \$43.50 plus postage & packing

Use this kit to store your WAV files on MMC/SD/SDHC cards. It can be used as a jukebox, a sound effects player or an expandable digital voice recorder. You can use it as a free-standing recorder or in conjunction with any Windows, Mac or Linux PC. Short form kit includes overlay PCB, SD card socket and electronic components.



MARINE ENGINE SPEED EQUALIZER KIT

KC-5488 \$23.25 plus postage & packing

The Engine Speed Equalizer Kit takes the tacho signals from each motor and displays the output on a meter that is centered when both motors are running at the same RPM. When there's a mismatch, the meter shows which motor is running faster and by how much. You simply adjust the throttles to suit. Short form kit only, requires moving coil panel meter (Cat. QP-5010 \$9.00).

- 12VDC
- PCB and specified components



MULTIFUNCTION ACTIVE FILTER MODULE KIT

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- Input impedance: 47kΩ
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- Current: 40mA max
- S/N ratio: >100dB @ 1V 22Hz-22kHz filter



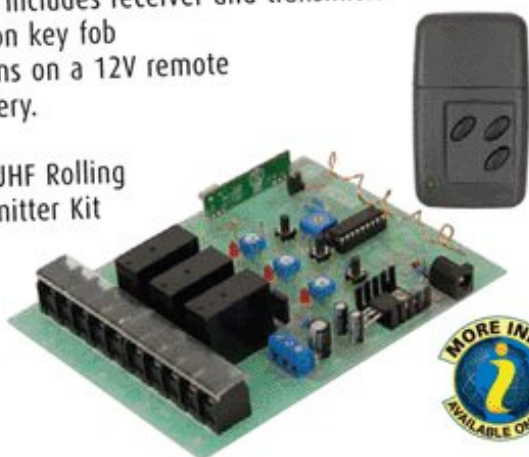
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UHF Rolling Code Remote Switch Kit

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Additional UHF Rolling
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KC-5484
\$23.25



Solar Powered Shed Alarm Kit

KC-5494 \$17.50 plus postage & packing

A simple solar powered alarm that's great for sheds and other remote locations that lack mains power - a boat on a mooring, for example. This kit has 3 inputs and works with a variety of sensors, plus all the normal entry/exit delay etc. Short form kit only - add your own solar panel, 12V SLA battery, sensors and siren. See website for specs.

- Supply voltage: 12VDC
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This kit intercepts and alters the signal from engine sensors that supply a voltage signal to the engine control unit (ECU). Restore correct air/fuel ratios after engine modifications, prevent engine boost cuts; or alter sensor signals for improved drivability. Requires hand controller for programming, RS232 cable and a suitable input signal. Kit includes PCB, case and electronic components.



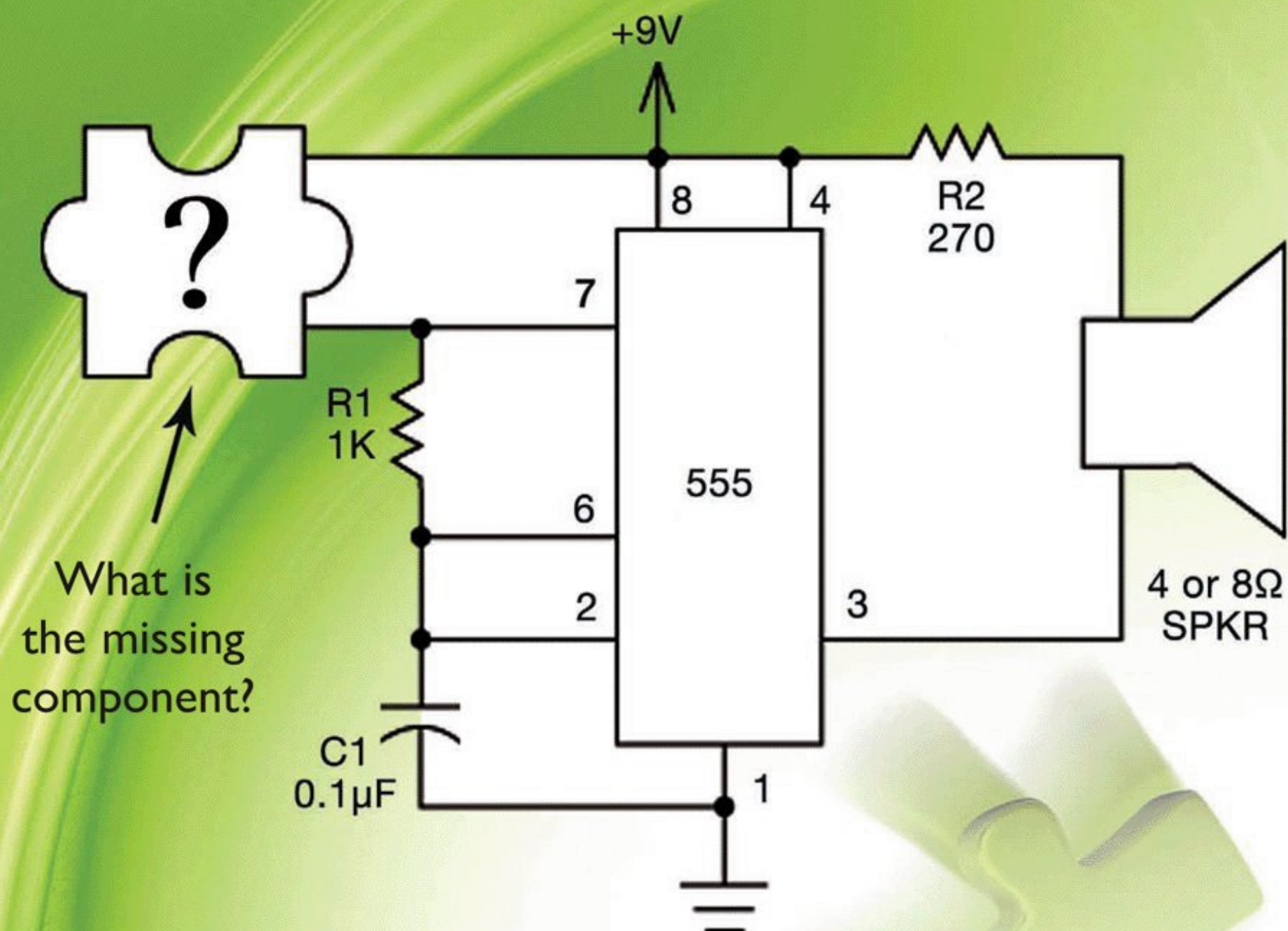
Recommended with this kit:
• Hand Controller Cat. KC-5386 \$39.50
• RS232 Cable Cat. WC-7502 \$7.00



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Jaycar
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Can You Guess the Missing Component?



Amateur electronic musician Joe Rhythm is planning a one-man video concert that he plans to post on YouTube. Controlling his array of instruments requires both hands and he wants to build a pressure-sensitive tone generator that he can control with a free finger or even an elbow or foot. Joe quickly whipped up a simple tone generator using parts from his bench stock. Since there wasn't enough time to order a pressure sensor, he improvised by making one from materials he had on hand. What did he use? Go to www.jameco.com/search6 to see if you are correct and while you are there, sign-up for our free full-color catalog.

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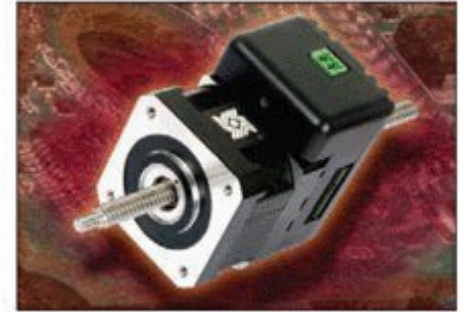
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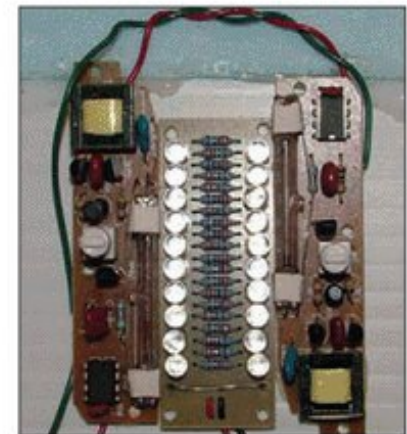
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Busy as a BeAVR.

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Nuts & Volts (ISSN 1528-9885/CDN Pub Agree #40702530) is published monthly for \$26.95 per year by T & L Publications, Inc., 430 Princland Court, Corona, CA 92879. PERIODICALS POSTAGE PAID AT CORONA, CA AND AT ADDITIONAL MAILING OFFICES. POSTMASTER: Send address changes to **Nuts & Volts, P.O. Box 15277, North Hollywood, CA 91615** or Station A, P.O. Box 54, Windsor ON N9A 6J5; cpcreturns@nutsvolts.com.



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by Bryan Bergeron, Editor

DEVELOPING PERSPECTIVES

Starting Out

One of the most common topics of my email discussions with young readers is how to get started in electronics. To someone new to the hobby, it can be a bewildering first encounter — there's the vocabulary, the physics, the components, the tools, and (of course) the cost. My advice to novices is to start simple, establish a good work environment and habits, use the appropriate tools and instruments, and, above all, find a mentor.

If you're just starting your adventure in electronics, keep it simple and affordable. You don't need a room full of test gear or a \$1,000 parts library to get going. I'd start with teardowns. Take apart and analyze whatever you can get your hands on — from kitchen appliances to discarded computers. You really shouldn't try building something before you've studied how electrical and electronic devices are put together. Stick with low voltage devices. There's no need to get knocked to the floor while disassembling an old TV set that hasn't been fully discharged. Establishing a good work environment and work habits is essential — especially when you start dealing with live components and devices. Your work area should be well lit, adequately ventilated, and immune to flying pieces of wire and the spray of molten solder. A Formica countertop or kitchen table will do; just protect the surface from dings, scratches, and the heat from

your soldering iron. You can move up to a butcher-block workbench with a vise or third-hand tool later.

As far as work habits go, definitely get in the habit of wearing safety glasses. It's amazing how far a resistor lead can travel once it's clipped from a circuit board. Or, how far solder can splash. Protect your vision. You should also develop the habit of washing your hands. Even if you use leadless solder, components and circuit boards invariably carry traces of heavy metals and other noxious substances that you shouldn't ingest. From a safety perspective, use the tools most appropriate for the job. Assuming your tool kit includes the basics — a soldering iron, needlenose pliers, crescent wrench, diagonal cutters, and a few screwdrivers — this means using the crescent wrench to remove a nut. If you use the needlenose pliers, they'll likely slip and either pinch your hand or impale your foot. Not a good outcome for you or your tools.

As you gain experience, you'll want to increase your arsenal of tools to include tweezers, a hex driver set, drill, and illuminated magnifying glass. A lightweight, desktop vise will enable you to work with small devices and rework circuit boards. Your interests will dictate the types of tools you'll eventually need. For example, if you're into appliances, you'll want tough tools made for heavy gauge work. Conversely, if you're working with surface-mount

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Webstore orders only 1-800-783-4624

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Subscriptions

Toll Free 1-877-525-2539

Outside US 1-818-487-4545

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North Hollywood, CA 91615

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components, you'll appreciate delicate, finely crafted tools. Learn the operating range of your tools – most cutters and pliers are rated for wire type and gauge. The only instrument you really need on your workbench is a digital multimeter. You'll find the resistance function useful for tracing circuits, verifying component values, and the voltage function indispensable for verifying that high voltage capacitors are discharged. You may be dreaming of an oscilloscope, but you really don't need one until you start designing and debugging complex digital circuits. In the meantime, you can keep an eye out for bargains on eBay and local flea markets for deals on used but functional equipment. As you progress to designing and building your own circuits, you can gradually add the tools and instruments that suit your particular interests and budget. The most important prescription for success is to find a mentor – preferably someone who has worked professionally in the field of electronics. The ideal mentor will be able to teach you diagnostic and construction techniques while keeping you motivated when you hit the inevitable speed bumps. Who knows, your mentor might even steer you into a career in electronics engineering. **NV**

11:48 AM
Why not try a different approach before you head to lunch?

1:03 PM
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10:05 AM
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9:00 AM
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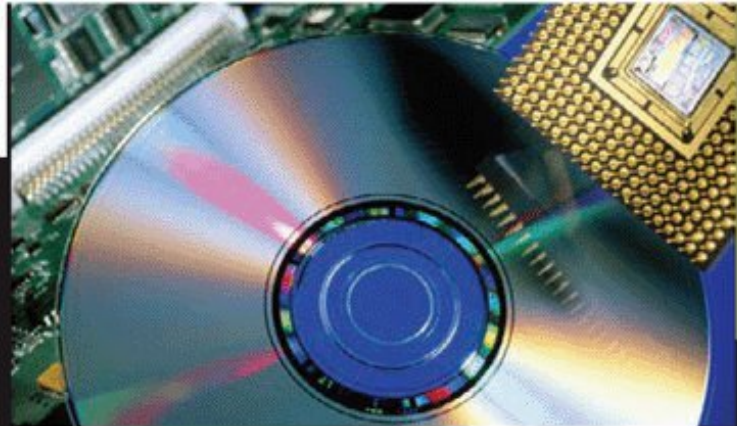
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TECH KNOWLEDGEY 2010

EVENTS, ADVANCES, AND NEWS

■ BY JEFF ECKERT

ADVANCED TECHNOLOGY

WIPING OUT WIRING, PART 1

With the development of wireless routers, Bluetooth devices, wireless keyboards, et al., we've made pretty good progress in the quest to eliminate all those pesky wire interconnects in the office. But some Purdue University (www.purdue.edu) researchers are working on a technology that could cut the communications copper for all of the devices in your home or office, including HD TV, radio, projectors, and whatever. The idea is to transmit all communications from a single base station which would consist of a dedicated computer or perhaps just a card inserted into an expansion slot in an existing one.

"The central computer would take charge of all the information processing, a single point of contact that interacts with the external world in receiving and sending information," according to Prof. Minghao Qi. We're not talking about conventional RF technology, however. Rather than operating in the noisy 2.4 GHz band, the Purdue system transmits at 60 GHz. This is accomplished

■ Diagram of a silicon "microring resonator" that enables fast laser pulses to be converted to RF signals.

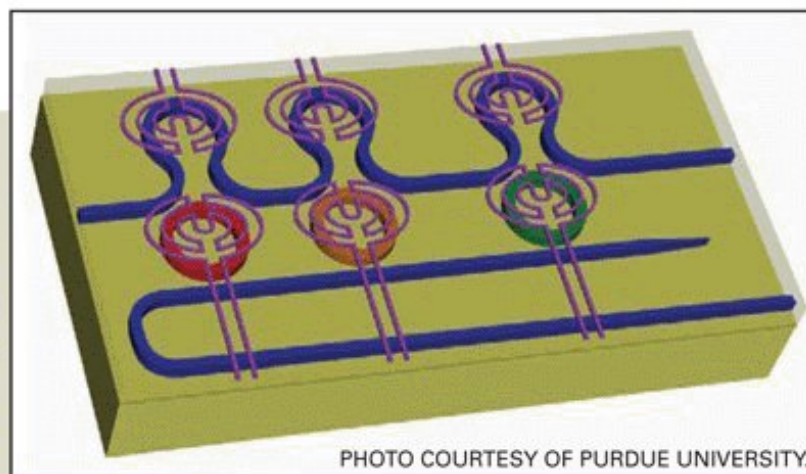


PHOTO COURTESY OF PURDUE UNIVERSITY.

by converting ultrafast laser pulses into RF signals using newly developed "microring resonators" that sidestep the limitations of standard digital-to-analog converters, and eliminate the need for large "bulk optics" systems that use optical components to achieve the same thing. By combining a series of microrings into a programmable "spectral shaper," the system can be set to transmit only certain frequencies. Because no one — including the FCC — regulates signals in the range of 57 to 64 GHz, the system could be implemented on a worldwide basis with universal compatibility. Purdue filed for a provisional patent last January, but Qi noted that the technology is still at least five years away from commercialization. ▲

WIPING OUT WIRING, PART 2

Taking a more direct approach to converting light into broadband is a concept recently demonstrated by Jelena Vucic and associates, of the Fraunhofer Institute for Telecommunications, Heinrich Hertz Institute (www.hhi.fraunhofer.de). The idea here is to harness things like simple desk lamps to transmit visible-frequency wireless data. You simply impose high frequency flicker on all of the lights in a room in unison. A minor snag is that incandescent and fluorescent lights aren't capable of flickering fast enough, so the lights have to be LED based. Although present commercial LEDs have a limited bandwidth, the Fraunhofer researchers have achieved a tenfold bandwidth increase by filtering out the blue part of the spectrum. Their first wireless system achieved data rates of 100 Mb/s in the lab, and the latest upgraded system has hit 230 Mb/s. This still isn't earth-shattering speed, but Vucic says a more sophisticated modulation signal should allow the rate to be doubled again. An interesting consideration is that — unlike RF signals — visible-light transmissions cannot pass through walls or other opaque barriers. That's both a limitation and an advantage, though, as securing your facility against eavesdroppers would be pretty much just a matter of closing your curtains. ▲

MAXWELL'S DEMON DISCOVERED?

A team at Massachusetts Institute of Technology (www.mit.edu) has figured out a way to transform polyethylene — usually a great electrical insulator but poor heat conductor — into a material that can dissipate heat as well as most metals. This has obvious potential in applications ranging from heatsinks in electronics to solar collectors and heat exchangers. The interesting facet is that (according to MIT) the material will "conduct heat very efficiently in just one direction unlike metals which conduct equally well in all directions." This sounds eerily similar to James Clerk Maxwell's hypothetical concept of a two-chambered box in which a gatekeeper (the demon) would allow only high velocity molecules to pass from chamber A to B and low velocity ones from B to A, thus increasing the temperature in B and lowering it in A. This would provide an exception to the second law of thermodynamics. Can the MIT material qualify as the demon? Well, not likely. But it should make one heck of a thermos bottle. ▲

COMPUTERS AND NETWORKING

BUTTERFLIES ARE NOT FREE

You know things are slow in the PC business when the most newsworthy item is based on a fashion statement, but here it is. Back in March, Hewlett Packard and "world-renowned" designer Vivienne Tam (who?) brought forth the concept of "digital clutch chic" in the form of an HP Mini 210 netbook incorporating Tam's "Butterfly Lovers" design motif. Said Tam, "To me, butterflies symbolize love, freedom, independence, and transformation. Together we bring life, color, and personality to the computer world, creating fashionable technology for modern women."

Billed as the next must-have accessory, the unit includes a built-in webcam that turns it into an instant digital mirror,



■ Designer version of HP's Mini 210 netbook.

allowing the user to discreetly admire her botox or wipe caviar off her chin. It Vincorporates a special butterfly start menu, custom Tam icons, and three wallpapers that coordinate with the design. In addition, it comes with a matching microfiber (i.e., fake) suede sleeve and (optionally) a Butterfly Lovers wireless mouse and a set of in-ear headphones to take advantage of the Beats Audio feature. "Fashion-forward women around the globe can reserve theirs now at www.hp.com/vivienntam." Note, however, that the Tam Edition netbook starts at \$599 (\$804.98 with the recommended options), as opposed to the \$279 list on the standard model. You can always get really nice butterfly decals for a buck or two at your local Walmart instead. ▲

ALL-IN-ONE FOR HOME OFFICE

Kodak's latest offering for the home office market is the ESP Office 6150 all-in-one printer, with "all" meaning inkjet printing, copying, scanning, and fax capabilities in one unit. The 6150 continues Kodak's marketing focus on the price of its ink cartridge which it says is the lowest in the industry. The company claims that its products save consumers an average of \$110 per year on ink based on as few as four pages per day. In addition to the basic four functions, the 6150 offers Wi-Fi and Ethernet connectivity with a range of devices, including Blackberry smart phones, iPhones, and the iPod Touch. You get print rates of up to 32/30 ppm and copy rates of 27/26 cpm (black/color), a 200-page paper tray, two-sided printing, and scan resolution up to 1,200 dpi. Faxing is done at 33.6 kbps, and the machine includes a 30-page document feeder. The list price is \$229. ▲



■ Kodak's ESP Office 6150 offers printing, faxing, copying, and scanning in one unit.

INDUSTRY AND THE PROFESSION

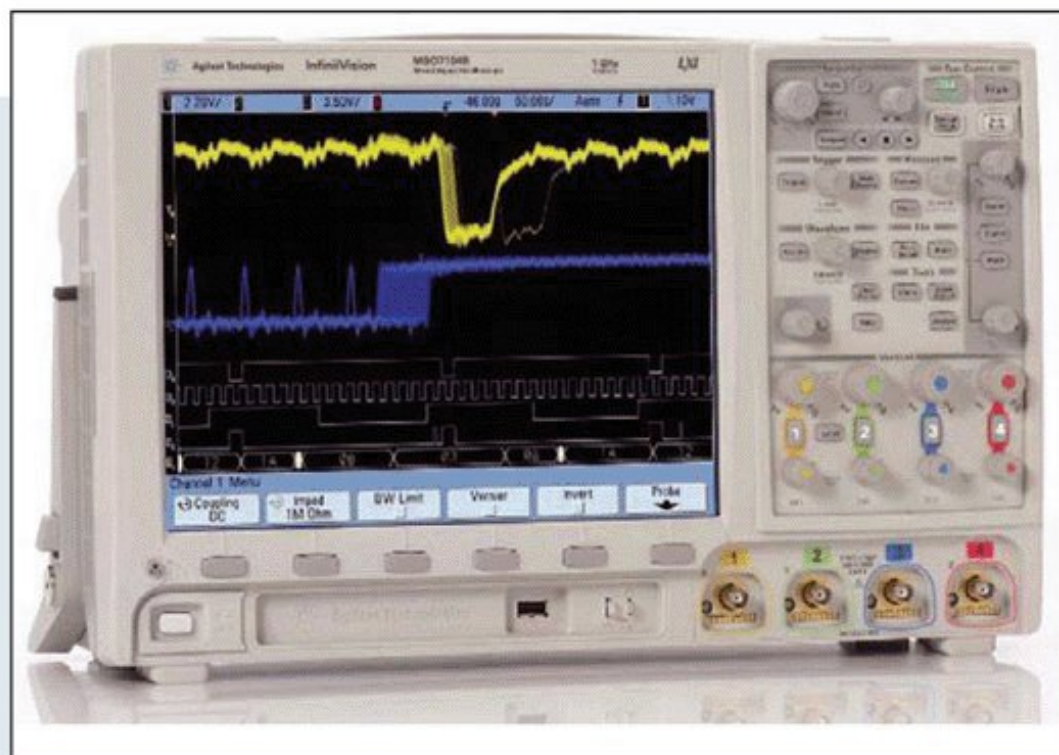
WIND FARM ANNIVERSARY

Wind farms still seem a bit futuristic but, in fact, 2010 marks the 30th anniversary of the world's first installation. It was created by US Windpower and employed 20 turbines rated at 30 kW each, perched atop New Hampshire's Crotched Mountain. Unfortunately, the company underestimated how much wind would be available, and the turbines experienced repeated mechanical failure, so the Crotched Mountain facility itself was a failure. The company later changed its name to Kenetech, improved its designs, and built some wind farms in California. At one point, it was the world's number one turbine manufacturer and wind farm developer. However, continuing design problems, overly optimistic development plans, and a weak market eventually contributed to its downfall, and it filed for bankruptcy in 1996. Enron Wind acquired its turbine designs and other assets, which in 2002 finally were bought by GE for about \$358 million in a court-supervised bankruptcy auction. ▲

CIRCUITS AND DEVICES

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If you're shopping for a new oscilloscope, Agilent has a bunch of new choices for you. It recently added 14 new models to the InfiniiVision 7000 series mixed-signal and digital-storage oscilloscope lineup, offering bandwidths from 100 MHz to 1 GHz. In addition to the standard analog representations, they provide digital signal capture and serial bus triggering and decode. Custom ICs provide accelerated operation and display up to 100,000 waveforms per second to capture signal detail and intermittent events. It offers a range of features including a 12.1 inch display of up to 20 simultaneous channels; rapid core-assisted debug of designs with Xilinx or Altera FPGAs; segmented memory for analysis of laser pulses, radar bursts, and serial packets; offline PC viewing and sharing of previously acquired scope data; and RF contextual viewing of scope data using vector signal



■ Agilent's InfiniiVision 7000B series oscilloscope.

analysis software. Details are available at www.agilent.com/find/7000B. Prices range from \$4,995 for the base 100 MHz unit and top off at \$19,500. ▲

AFFORDABLE NIGHT VISION

Many of us have kicked around the idea of buying a night vision system but have been put off by the price. But Bushnell (www.bushnell.com) may have a deal for you within its StealthView product lineup. If you can live with a monocular unit and don't need military-level technology, the Nightwatch unit might be the way to go. It uses active rather than passive infrared illumination, so a human subject could conceivably figure out what you're up to. If your objective is general security and surveillance, cave exploration, night fishing and boating, wildlife observation, or just fooling around, that shouldn't be a problem either. The units use CMOS chips to convert light into an image that is displayed on an LCD flat panel screen in black and white, plus a video output port allows you to record images on a camcorder or laptop. All Stealthviews have dual IR illumination diodes: one is on at all times for short-range scenes, and the other is an IR spotlight that allows viewing of objects up to 200 ft (61 m) away. A waterproof model is available. The price is a bit difficult to tack down, as the Bushnell website offers the Nightwatch model for \$326.95. Amazon and other sites list it for as little as \$139, so it pays to shop around. ▲



■ Bushnell's Nightwatch displays objects at up to 200 ft.



■ Elma's light tubes — available in various colors, sizes, and configurations.

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If you're designing or building lighting for electronics, architecture, edge illumination, alarm systems, indirect illumination, etc., you might note Elma Electronic's expanded line of LED light tubes with new five and 10 mm options supplementing the existing six and eight mm ones. The tubes' modular design allows a range of lengths (up to 2 m) and shapes, and the housings come in double-ended or optional single-ended configurations. Cited features include a variety of light direction, brightness, and color options; high ESD resistance and mechanical strength; suitability for use on all infrared and vapor-phase soldering systems; and low current, long life operation. Pricing depends on volume, length, and configuration, so you'll need to visit www.elma.com for more information. NV

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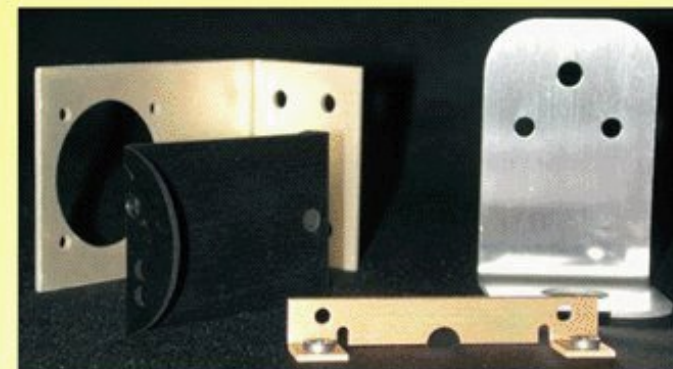
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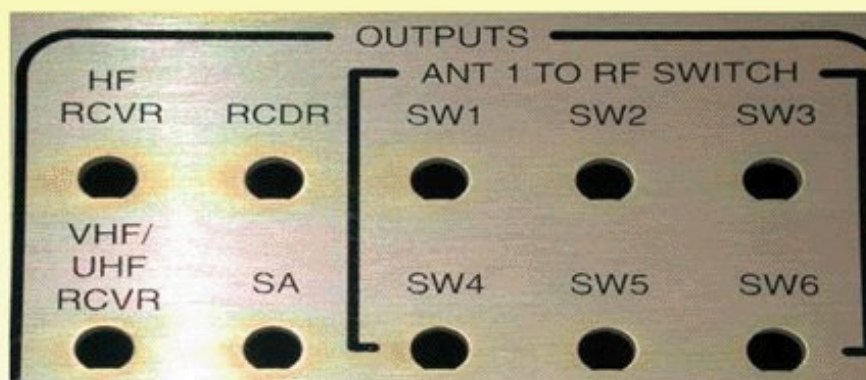
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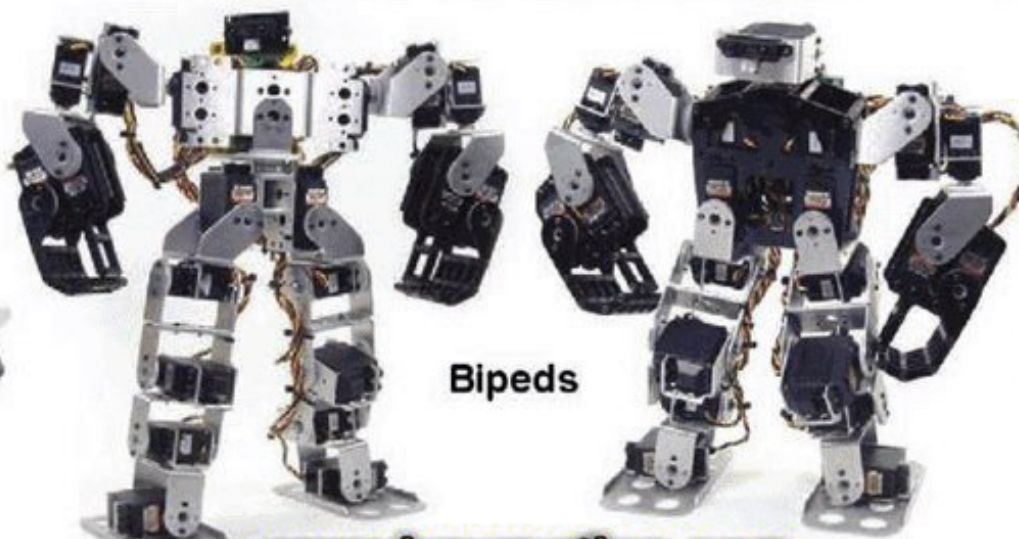
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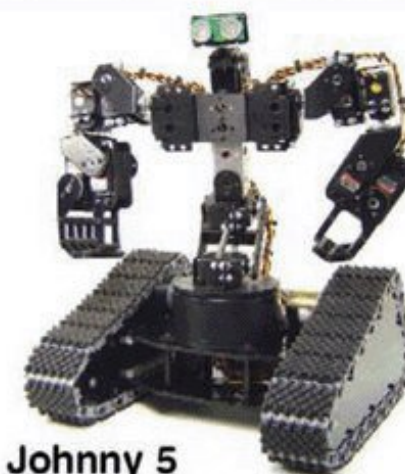
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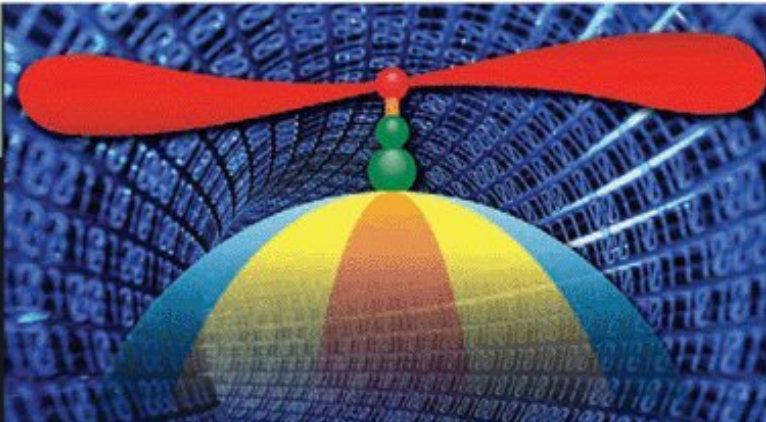


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■ BY JON WILLIAMS

SPINNING UP FUN WITH ENCODERS

In my dual life that crosses between the technical and entertainment worlds, I have the incredible good fortune to meet some really great people. Case in point: I was contacted by a cool cat named Wayne (dubbed “the Brain” by his friends) who (like me) is an electronics enthusiast and embedded programmer, who also works in show biz. Wayne’s entertainment gig is in music, engineering, and mixing songs for some amazing A-List Pop, R&B, and Hip-Hop artists. Wayne needed a little help with an encoder for a personal project. Coincidentally, one of my customers had asked about adding a local user interface to a product. So, while working with Wayne, I solved my own problem and will show you what I came up with so you can put it to use, too. And while we’re on the topic of expanding inputs with just a few I/O pins, I’m also going to show you how to apply an old trick to this new processor.

GRAY CODE IS BLACK AND WHITE

The encoder Wayne selected is called a Gray code encoder; in his particular case, it is a two-bit encoder. Gray code is different from regular binary code in that two successive values differ by only one bit — like this for the two-bit encoder we’ll be using:

`%11 → %01 → %00 → %10 → %11`

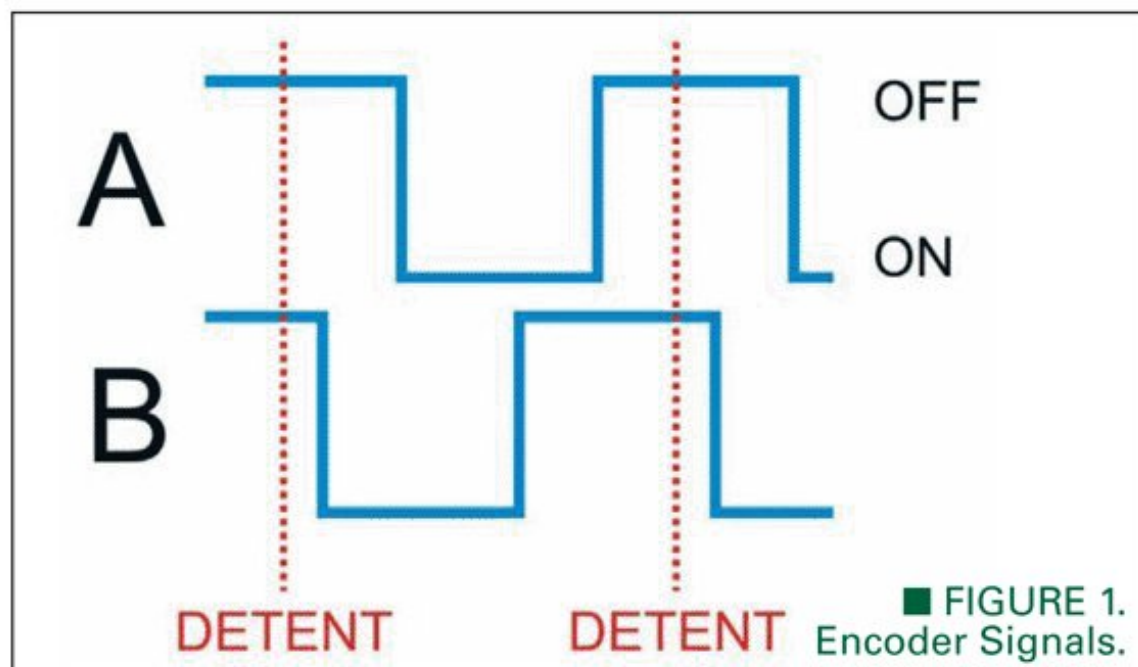
Note that as we move through the sequence in either direction, only one bit changes. This is, in fact, different from a two-bit binary sequence where we would go from %11 to %00 and two bits would change. Why is all this so

important? Well, despite best efforts in manufacturing, having two bits change at precisely the same time is darned near impossible, and a processor as fast as the Propeller could easily catch one changing before the other — resulting in a bad input. Gray code solves this with the single bit change between steps.

Dealing with a Gray code encoder is quite simple: scan the inputs; check for a change; and on a change, determine direction. Adding to the mix, Wayne’s encoder — and the one I went with for my own project board — has a pushbutton and detents. That is, it “clicks” when you turn the shaft. The button is no problem. We know how to debounce buttons and we can add that to the object code. The detents create an extra bit of work but once we understand how the encoder behaves, you’ll see it’s also pretty simple.

Figure 1 shows the output of the encoder using normally-open pins that are pulled up to Vdd — this comes right out of the datasheet so I matched it (see **Figure 2** for the schematic). Note the location of the detents (when both outputs are off) — we’ll adjust the object for this so that one piece of code will work with “detented” encoders, as well as those that freely spin and can stop at any output pattern.

Let’s jump in. My main goal with this object was to be able to initialize it, and then ask for the position value and button status — everything else is handled behind-the-scenes in the encoder cog. To keep things really flexible, we’ll allow the ability to reset the current position value; this will be



■ FIGURE 1.
Encoder Signals.

validated (and corrected if necessary) by the object.

Here's the method we'll call to initialize the encoder object:

```
pub init(base, btn, detent, lo, hi, preset)

    finalize

    enctiming := (clkfreq / 1_000) >> 2
    basepin   := base
    btnmask   := 1 < btn

    if detent
        hasdetent := true
        lolimit   := lo << 2
        hilimit   := hi << 2
        encoder   := preset << 2
    else
        hasdetent := false
        lolimit   := lo
        hilimit   := hi
        encoder   := preset

    cog := cognew(@grayenc, @encoder) + 1

    return cog
```

The first parameter is the base pin, which is the A pin of the encoder. To keep the code simple, we expect the next higher pin to be the encoder's B pin. The second parameter is the encoder's button input. Note that all three pins are active low, that is, they are pulled up to Vdd through 10K and will go low when active.

Next up is the true (non-zero) or false (zero) value that specifies whether the encoder has detents or not. Finally, we'll pass the low, high, and initial (preset) values for the driver. If, for example, we had an encoder with a base pin of 3, a switch pin of 5, is detented, will span from -100 to +100, and starts at zero, we would initialize it like this:

```
encoder.init(3, 5, true, -100, 100, 0)
```

When a detented encoder is used, the limits and preset values are shifted left by two, which is the same as multiplying by four. We have to do this to account for the steps in between each detent. Shifting negative values left for the range we would typically use is not a problem. I tested this theory on values down to minus 10 million – a value we'd never use in an actual project – just to make sure.

The range limits take priority over the preset value; if the preset is outside the specified range, the object will fix it. Let's have a look at that.

```
grayenc      rdlong tmp1, par
             mins   tmp1, lolimit
             maxs   tmp1, hilimit
             wrlong tmp1, par
```

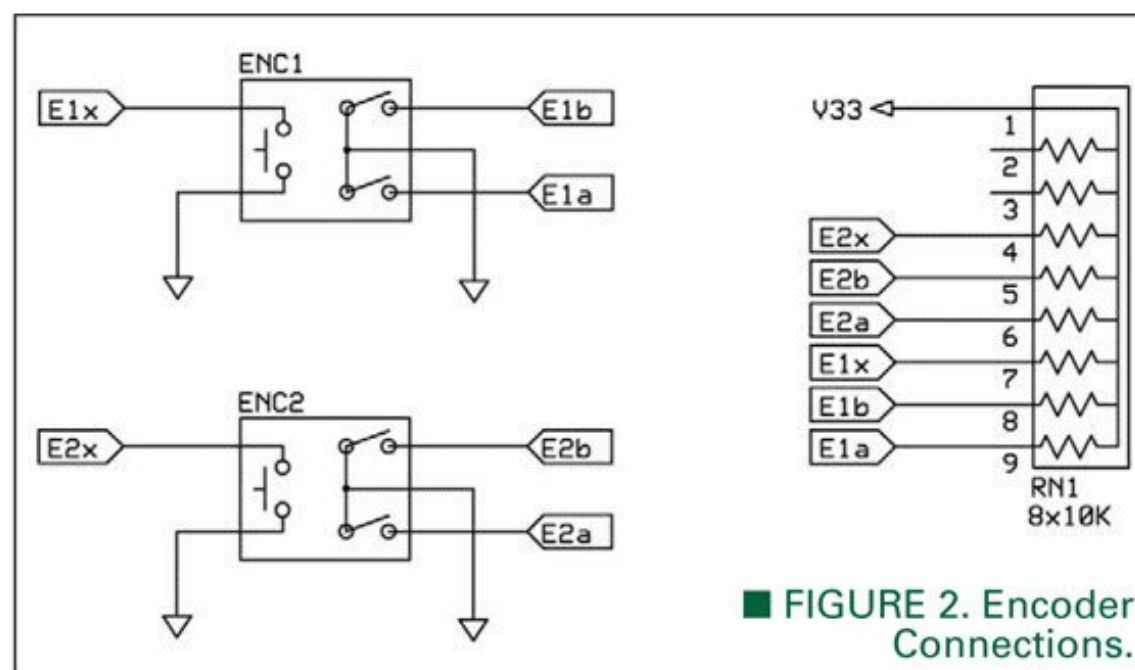


FIGURE 2. Encoder Connections.

At **par** is the address of the encoder value. After reading the preset value into **tmp1**, we use signed versions of **min** and **max** to ensure that it is within the stated bounds. Yes, we could have done this in Spin in the **init()** method, but it's easy and fast so it seemed like this was the best place to handle it.

Next up is basic initialization of the button debounce workspace, the previous scan result (stored in **oldscan**), and creating a timer. We don't need the timer for the encoder, but it does come into play for debouncing the button input.

```
setup      mov      btnwork, #0
           mov      tmp1, par
           add      tmp1, #4
           wrlong   btnwork, tmp1

           mov      oldscan, ina
           shr      oldscan, basepin
           and      oldscan, #%11

           mov      timer, cnt
           add      timer, enctiming
```

And now we get to the guts of it.

```
encloop    waitcnt timer, enctiming

scan       mov      newscan, ina
           mov      tmp1, newscan

chkbutton  test     btnmask, tmp1    wc
           if_c     mov      btnwork, #0
           if_nc    add      btnwork, #1
           max      btnwork, BTN_TM wc
           if_c     mov      tmp1, #0
           if_nc    mov      tmp1, IS_PRESSED
           mov      tmp2, par
           add      tmp2, #4
           wrlong   tmp1, tmp2
```

As always, delays are a breeze in PASM with the **waitcnt** instruction. I've set the encoder to run on a 250 microsecond loop. That way, if we get really zippy with



the encoder knob the program can still keep up.

The present state of the input pins is copied into `newscan`, and that is copied into `tmp1` where we'll use it to check on the button. To check the button input, we AND (using **test**) the button mask with `tmp1` and save the result in the Carry flag. We're using an active-low circuit, so a set Carry flag means that the button is not pressed. If that's the case, the value of `btnwork` is cleared. Otherwise, it's incremented.

The next step — using **max** — actually does two things for us: 1) It keeps the value of `btnwork` at the debounce timing limit to prevent a roll-over on a stuck switch; and 2) The Carry flag indicates whether `btnwork` is less than **BTN_TM** (set for 25 ms). If the Carry flag is set, the button is not fully debounced and we move zero to `tmp1`. Otherwise, we move **IS_PRESSED (true)** to `tmp1`, then write it to the hub at the address for the button status. Again, the encoder value address is stored in **par**, so four (for a long value) is added to this value to get the correct address of the button status variable.

With the button debounced (or not), we can check to see if the encoder moved. We'll start by isolating the encoder inputs and comparing them to the last scan.

```

chkencoder      shr      newscan, basepin
                  and      newscan, #%11
                  cmp      newscan, oldscan
wz
                  if_e     jmp      #encloop

```

Now you can see why we want the A and B pins in contiguous, ascending order on the inputs; we're simply shifting the scan value right by the base (A) pin number and masking off the other bits. This is compared to `oldscan` and if they're equal (i.e., no change), we jump right back to the top.

Okay, I know there's more than one of you hardcore types that might want to go willy-nilly on input mapping; maybe a PCB routing problem prevents keeping the pins contiguous and in ascending order. Here's what to do: Create pin masks for the A and B pins (just like we did for the button input) and then change the code like this:

```

chkencoder      mov      tmp1, #0
                  test     amask, newscan   wz
                  muxc     tmp1, #%01
                  test     bmask, newscan   wz
                  muxc     tmp1, #%10
                  mov      newscan, tmp1
                  cmp      newscan, oldscan wz
                  if_e     jmp      #encloop

```

As you can see, this version tests each input and moves them through the Carry flag, into the correct locations in `newscan`. I really like the **muxc** operator; this code snippet shows how useful it is, allowing us to move what's in C to any bit position of a variable. Remember, if you update the PASM code to handle non-contiguous

encoder pins you'll need to update the initialization of `oldscan` and add a B pin parameter to the **init()** method. Actually, I've done the work for you. (See `jm_grayenc2btnx.spin` in the download package at www.nutsvolts.com. This version allows us to disable the button pin, as well.)

Okay, let's say we have a change. What I use is an assembly version of a **case** structure, using the previous scan and comparing it to the value for a positive (clockwise) change.

```

case11          cmp      oldscan, #%11   wz
                  if_ne    jmp      #case01
                  cmp      newscan, #%01   wz
                  jmp      #update

case01          cmp      oldscan, #%01   wz
                  if_ne    jmp      #case00
                  cmp      newscan, #%00   wz
                  jmp      #update

case00          cmp      oldscan, #%00   wz
                  if_ne    jmp      #case10
                  cmp      newscan, #%10   wz
                  jmp      #update

case10          cmp      oldscan, #%10   wz
                  if_ne    jmp      #encloop
                  cmp      newscan, #%11   wz

```

You'll see that each section is identically constructed. If the new scan represents a clockwise move, the Z flag will be set. Otherwise, the Z flag will be cleared. The program then jumps to **update** which does the final routing.

```

update          rdlong    tmp2, par
                  if_nz     jmp      #decvalue

incvalue        adds     tmp2, #1
                  maxs     tmp2, hilimit
                  wrlong   tmp2, par
                  mov      oldscan, newscan
                  jmp      #encloop

decvalue        subs     tmp2, #1
                  mins     tmp2, lolimit
                  wrlong   tmp2, par
                  mov      oldscan, newscan
                  jmp      #encloop

```

At **update**, we retrieve the encoder value from the hub (because it could have been changed by the top-level program) and then increment or decrement it (based on the state of the Z flag) using the previously defined limits. The updated value is written back to the hub and we're done.

Well, almost — we need a method to read the current

encoder value in our top-level program.

```
pub read
    if hasdetent
        return (encoder ~> 2)
    else
        return encoder
```

Remember that situation with the detented encoders and the 4x multiplier? We multiplied the limits and preset value by four to accommodate the changes between clicks. Well, if we're using a detented encoder we can't simply shift the value right and return it to the intended range. Doing this on a negative number would cause it to go positive (because a 0 would be shifted into bit 31 — the sign bit). No worries. Spin has a really cool operator call Shift Arithmetic Right (~>). This operator does a right shift while maintaining the sign of the value, allowing the use of positive and negative numbers with no muss or fuss.

MORE EASY INPUT EXPANSION

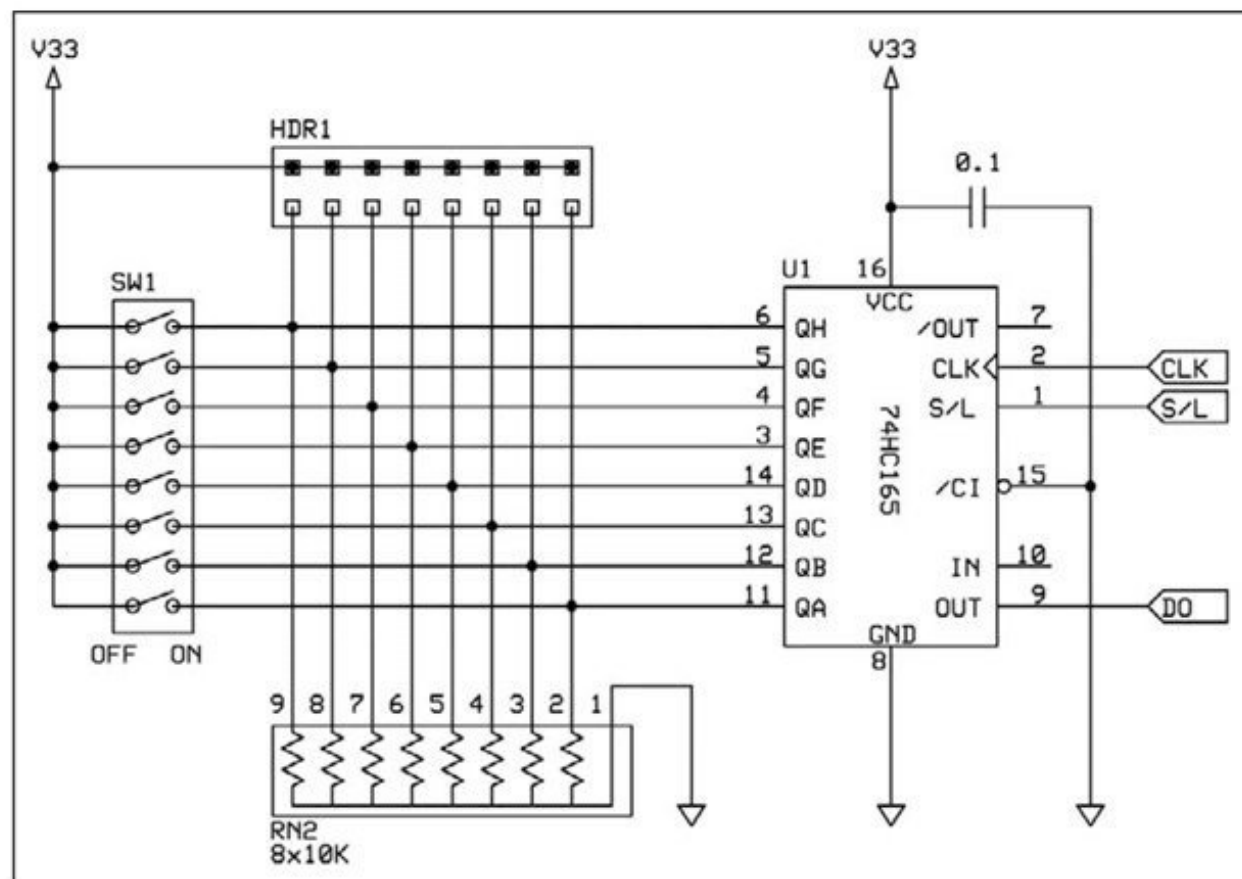
The product I mentioned in the opening is a 16-channel DMX controller that my business partner [and former Parallax engineer John Barrowman] and I designed. Since control of the outputs is paramount, we use P0..P15 for the output channels. With the RS-485 circuitry, a two-position mode switch, and other I/O requirements, we just didn't have enough pins on the Propeller to accommodate the nine-bit DMX address (like I did in my small DMX project last November).

The solution? Dirt easy! Use a 74x165 input shift register. With three pins, we get eight inputs; for the DMX address we simply connected bit 8 of the address switch directly to the Propeller. For my Propeller platform add-on, I used an eight-bit switch and a 2x8 header (to allow off-board switches); see **Figure 3** for the schematic.

If you've used the 74x165 with PBASIC or SX/B, you probably used **SHIFTIN** to read it. We can't do that with the Propeller directly anyway, as there is no built-in **SHIFTIN** instruction. You might be wondering why. For all its power, the Propeller has to squeeze the Spin interpreter into a single cog and that's tough work — so some niceties from PBASIC are not included.

No problem! We'll just write our own method, and no assembly (PASM) is required. The code that follows is very similar to PBASIC's **SHIFTIN**, reading a single byte in MSBFIRST mode — though it is set up to accommodate the Shift/Load line of the 74x165.

```
pub in165(ld, do, clk) | tmp165
    outa[ld]~~
    dira[ld]~~
    outa[clk]~
    dira[clk]~~
```



■ FIGURE 3. 74x165 Connections.

```
dira[do]~

outa[ld]~
outa[ld]~~

tmp165~
repeat 8
    tmp165 := (tmp165 << 1) | ina[do]
    outa[clk]~~
    outa[clk]~

return tmp165
```

As with PBASIC and SX/B **SHIFTIN**, this method takes care of setting the I/O pins used to achieve the required states. We start by making the Shift/Load pin an output and high; the Clock pin an output and low; and the Data Out (from the x165) an input.

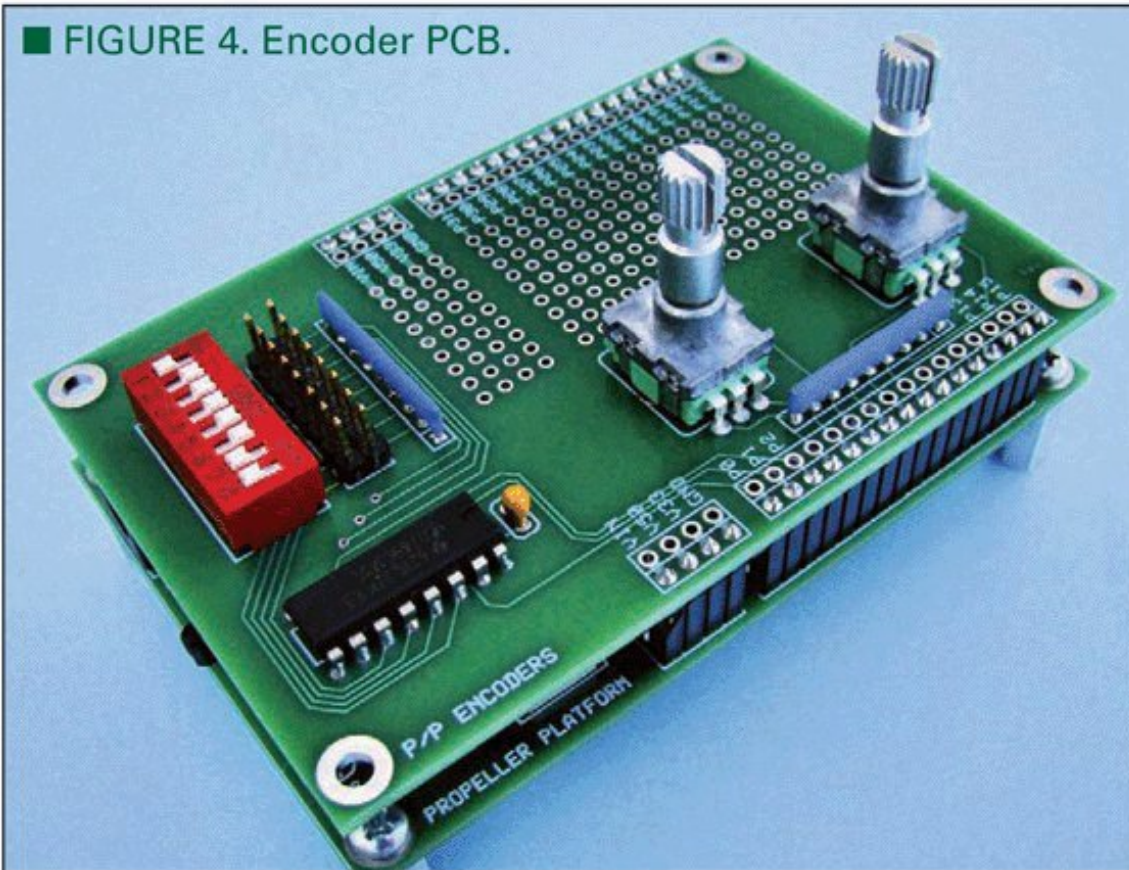
The Shift/Load line is blipped low, then back high; this latches the present state of the eight inputs to an internal register. With the data latched, it can be shifted into the Propeller using a **repeat** loop.

The first line of the repeat loop does all the hard work; it preps the work value by shifting it left one bit and then OR'ing the state of the DO pin to the value (in bit 0). After the bit is moved into the work variable,

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RN1, RN2	8x10K	Mouser 81-RGLD8X103J
SW1	DIPx8	Mouser 611-BD08
U1	74HC165	Mouser 595-CD74HC165E
PCB		ExpressPCB
		www.mouser.com
		www.expresspcb.com

■ FIGURE 4. Encoder PCB.



the Clock line is blipped high, then back low to get the next bit.

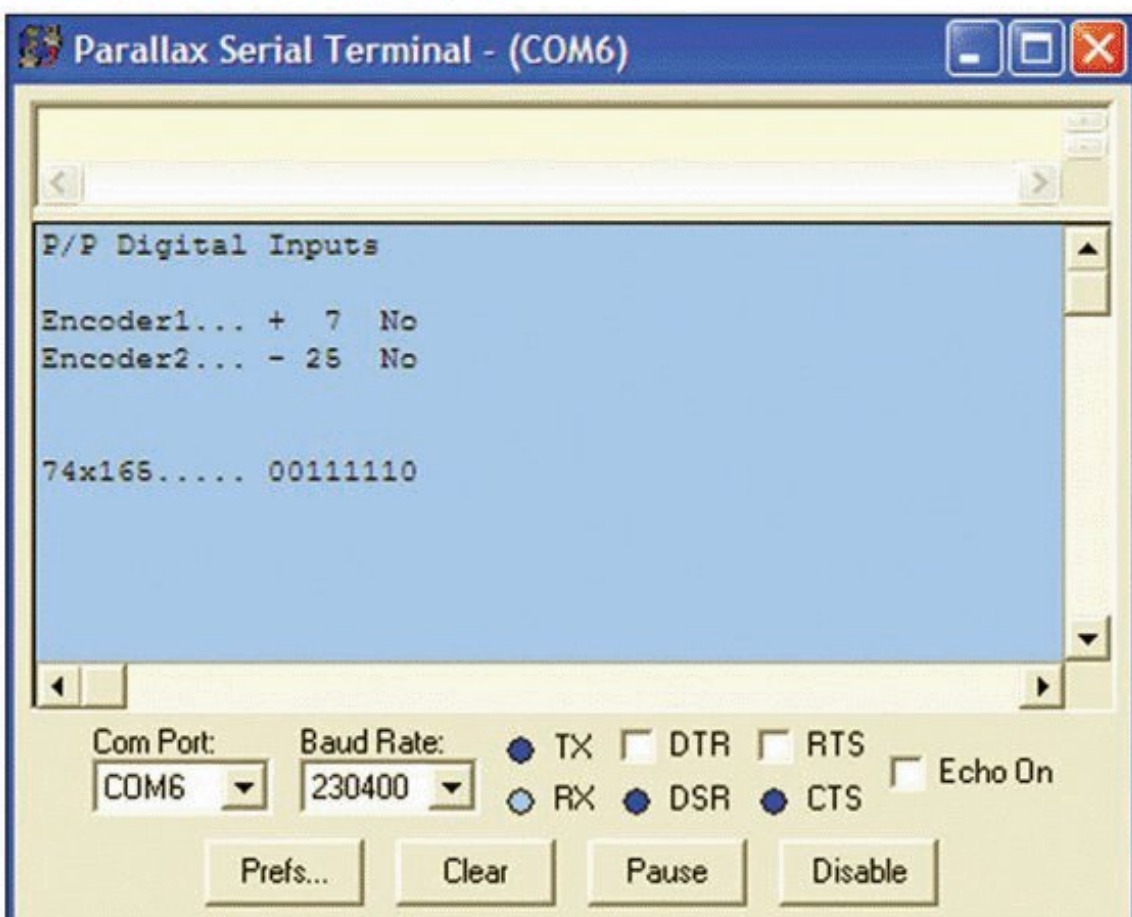
One of the things that Spin does not have is dot notation for bits like we've used in PBASIC and SX/B. For example, what if we wanted to convert the previous routine to shift the bits in LSB first? Here's the change that makes that happen:

```
repeat 8
  tmp165 := (tmp165 >> 1) | (ina[do] << 7)
```

In this case, we shift the work variable one bit right and then OR the DO value into bit 7. Note that we had to shift the DO bit before the OR operation. There's one more trick we could use: the reverse (><) operator. For example, we could create a global constant called LSBFIRST that would be applied after the value is shifted in like this:

```
repeat 8
```

■ FIGURE 5. Demo Output.



```
tmp165 := (tmp165 << 1) | ina[do]
outa[clk]~~
outa[clk]~
```

```
if LSBFIRST
  tmp165 ><= 8
```

While I haven't personally needed to use more than one 74x165 with a Propeller project, it's certainly a possibility. Here, then, is a final version of the routine that accommodates the number of bits to shift, as well as the shift mode. With this version of the routine, we could read up to four daisy-chained '165s into a single, 32-bit long one.

```
pub in165x(ld, do, clk, bits, mode) | tmp165

  outa[ld]~~
  dira[ld]~~
  outa[clk]~~
  dira[clk]~~
  dira[do]~

  outa[ld]~
  outa[ld]~~

  tmp165~
  bits <#= 32
  repeat bits
    tmp165 := (tmp165 << 1) | ina[do]
    outa[clk]~~
    outa[clk]~

  if (mode == LSBFIRST)
    tmp165 ><= bits

  return tmp165
```

The changes should be apparent. We'll limit the bit count to 32 for obvious reasons, update the **repeat** loop to use the *bits* parameter, then use the *mode* parameter with *bits* to adjust if LSBFIRST (*mode* = 0) is desired.

Since I've already made use of the 74x165 in two Propeller designs and I anticipate using Gray code encoders in a couple more, I created a little prototyping

JON WILLIAMS

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RESOURCES

PARALLAX, INC.

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PropBASIC

www.propbasic.com

add-on for the Propeller platform that includes the '165 and two encoders. These components don't take much space so I filled the rest with pads to place other components. **Figure 4** show the board attached to my original Propeller platform. **Figure 5** shows the output of a simple demo using the Parallax Serial Terminal through the programming connection.

PROPBASIC FOLLOW-UP

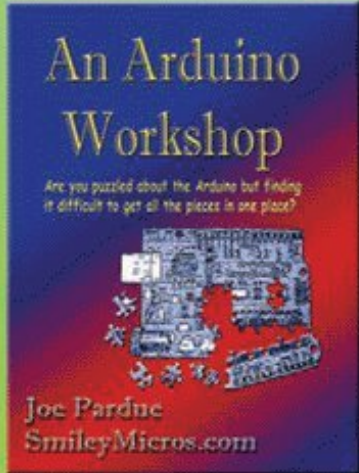
Wow, the response to PropBASIC was really amazing. To be honest, I was a little surprised, but then I really shouldn't be, should I? Those of us with Parallax experience have a lot of time with BASIC and this new tool made moving to the Propeller easier for some PBASIC and SX/B users.

Of course, things got even better when Brad Campbell (an Australian Propeller programmer and very nice guy), integrated the PropBASIC compiler into his BST (Brad's Spin Tool) IDE. What does this mean? Well, if you looked past the Propeller to something like, say, the Arduino because of the availability of a cross-platform development tool, well ... time to drop the single-core processor and move on up to the multi-core Propeller. With BST, you can program the Propeller in Spin, PASM, or PropBASIC, on nearly any Windows, Mac, or Linux PC. Now, *that's* cool!

The easiest way to get the BST IDE and PropBASIC compiler files you need is through links at www.propbasic.com.

Before I close, let me correct a small error in my last column. When an IDE like the Propeller Tool or BST is downloading to the Propeller, it is the Propeller – not the IDE as I misstated – that makes the adjustment for baud rate. This makes better sense; typically, the receiver does the “auto baud” detection and configuration. I apologize for any confusion.

Okay, then. Until next time – on a PC, a Mac, or Linux box – have fun and keep spinning and winning with the Propeller. **NV**




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All settings can be changed without taking the cover off! Enter the setup mode from the front panel and step through the menu to make all of your adjustments. A two line LCD display shows you all the settings! In addition to the LCD display, a front panel LED indicates PLL lock so you know you are transmitting.

Besides frequency selection, front panel control and display gives you 256 steps of audio volume (left and right combined) as well as RF output power. A separate balance setting compensates for left/right differences in audio level. In addition to settings, the LCD display shows you "Quality of Signal" to help you set your levels for optimum sound quality. And of course, all settings are stored in non-volatile memory for future use!

Both the FM30 and FM35WT operate on 13.8 to 16VDC and include a 15VDC plug-in power supply. The stylish black metal case measures 5.55"W x 6.45"D x 1.5"H. (Note: After assembly of this do-it-yourself hobby kit, the user is responsible for complying with all FCC rules & regulations within the US, or any regulations of their respective governing body. FM35BWT is for export use and can only be shipped to locations outside the continental US or valid APO/FPO addresses or valid customs brokers for end delivery outside the continental US.)

FM30B	Digital FM Stereo Transmitter Kit, 0-25mW, Black	\$199.95
FM35BWT	Digital FM Stereo Transmitter, Assembled, 0-1W, Black (Export ONLY)	\$299.95

Pocket Audio Generator

A perfect test source for stereo line inputs on any amplifier or mixer. Provides 50Hz, 100Hz, 1kHz, 10kHz, & 20kHz tones, plus 32 bit digital pink noise. Great to help you identify cables or left/right reversals! Stereo RCA line level outputs. Uses 2xCR2025, not included.



K8065	Pocket Audio Generator Kit	\$32.95
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Pocket Vu Meter

Hand held audio level meter that fits in your pocket! Built-in mic picks up music and audio and displays it on an LED bargraph. Includes enclosure shown. Runs on one 3V Li-Ion button cell, not included. If you ever wanted an easy way to measure audio levels, this is it!



MK146	Pocket Vu Meter Kit	\$8.95
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Mini LED Light Chaser

This little kit flashes six high intensity LEDs sequentially in order. Just like the K80302 to the right does with incandescent lights. Makes a great mini attention getter for signs, model trains, and even RC cars. Runs on a standard 9V battery.



MK173	Mini LED Light Chaser Kit	\$15.95
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Running Light Controller

Controls and powers 4 incandescent lights so they appear to "travel" back and forth (Like the hood on KITT!). Great for the dance floor or promotional material attention getters, exhibits, or shows. Runs on 112-240VAC.



K8032	4-Channel Running Light Kit	\$38.95
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Digital Voice Changer

This voice changer kit is a riot! Just like the expensive units you hear the DJ's use, it changes your voice with a multitude of effects! You can sound just like a robot, you can even add vibrato to your voice! 1.5W speaker output plus a line level output! Runs on a standard 9V battery.



MK171	Voice Changer Kit	\$14.95
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Steam Engine & Whistle

Simulates the sound of a vintage steam engine locomotive and whistle! Also provides variable "engine speed" as well as volume, and at the touch of a button the steam whistle blows! Includes speaker. Runs on a standard 9V battery.



MK134	Steam Engine & Whistle Kit	\$11.95
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Laser Trip Sensor Alarm

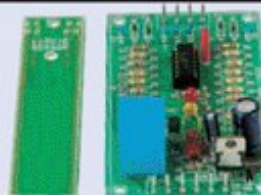
True laser protects over 500 yards! At last within the reach of the hobbyist, this neat kit uses a standard laser pointer (included) to provide both audible and visual alert of a broken path. 5A relay makes it simple to interface! Breakaway board to separate sections.



LTS1	Laser Trip Sensor Alarm Kit	\$29.95
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Liquid Level Controller

Not just an alarm, but gives you a LED display of low, middle, or high levels! You can also set it to sound an alarm at the high or low condition. Provides a 2A 240VAC rated relay output. Runs on 12-14VAC or 16-18VDC.



K2639	Liquid Level Controller Kit	\$23.95
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Electret Condenser Mic

This extremely sensitive 3/8" mic has a built-in FET preamplifier! It's a great replacement mic, or a perfect answer to add a mic to your project. Powered by 3-15VDC, and we even include coupling cap and a current limiting resistor! Extremely popular!



MC1	Mini Electret Condenser Mic Kit	\$3.95
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Sniff-It RF Detector Probe

Measure RF with your standard DMM or VOM! This extremely sensitive RF detector probe connects to any voltmeter and allows you to measure RF from 100kHz to over 1GHz! So sensitive it can be used as a RF field strength meter!



RF1	Sniff-It RF Detector Probe Kit	\$27.95
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The High Tech Spotlight!

50W FM Station-In-A-Box

- ✓ 50w RF output!
- ✓ Dual program source decks!
- ✓ Laptop input!
- ✓ USB input!
- ✓ Dual mics, antenna, and all accessories!
- ✓ Just plug it in and you're on-the-air!



YES, a complete FM stereo radio station in-a-box! We pioneered the concept over a decade ago, and now thousands of them are deployed around the world!

The concept? It's simple. Whether your application is for disaster preparedness, military, educational, LPFM, or standard FM backup, wherever you may need to get on-the-air quick, without any hassles, the Ramsey PXB series is your immediate solution... Setup the antenna, plug it in, and you're on-the-air!

This 50W version is based on our proven and ultra reliable FCC Certified PX50 FM stereo transmitter designed for simple operation via the front panel navigation switch matrix. All controls and status messages are displayed on the 2 line by 20 character vacuum fluorescent display. Automatic protection circuits are designed to keep you on the air, rather than off. To compliment the transmitter we include our 3.4dB gain omnidirectional FM broadcast antenna and 100' of low loss LMR400 feed line with pre-assembled & tested connectors.

From there we give you 2 separate CD-MP3-SD-USB media players as well as an external (laptop, etc) input, all prewired into a professional 5 channel stereo mixer. 2 dynamic handheld microphones, XLR cables, clips, and desk stands are included for local origination. We top it all off with two sets of professional stereo monitor headphones.

The entire unit is factory assembled in a small 6 rack unit mil-spec shock case, and burned in at full power for 12 hours. Over 15 different models are available, with power ratings from 50 watts to 1,000 watts. Visit www.ramseyfm.com for details.

PXB5006D93S	FM Radio Station	\$5195.00
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High Power LED Driver

High power LED's have finally found their way into the hobbyist budget, but now you need a driver! This little board provides the accurate and constant current need to drive them. Delivers 350mA or 700mA at a constant current



K8071	High Power LED Driver Kit	\$14.95
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Electronic Watch Dog

A barking dog on a PC board! And you don't have to feed it! Generates 2 different selectable barking dog sounds. Plus a built-in mic senses noise and can be set to bark when it hears it! Adjustable sensitivity! Unlike the Saint, eats 2-8VAC or 9-12VDC, it's not fussy!



K2655	Electronic Watch Dog Kit	\$39.95
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Stereo Ear Super Amplifier

Ultra high gain amp boosts audio 50 times and it does it in stereo with its dual directional stereo microphones! Just plug in your standard earphone or headset and point towards the source. Incredible gain and perfect stereo separation!



MK136	Stereo Ear Amp Kit	\$9.95
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Broadband RF Preamp

Need to "perk-up" your counter or other equipment to read weak signals? This preamp has low noise and yet provides 25dB gain from 1MHz to well over 1GHz. Output can reach 100mW! Runs on 12 volts AC or DC or the included 110VAC PS. Assmb.



PR2	Broadband RF Preamp	\$69.95
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Vintage Battery Eliminator

Collectors come across some great deals on antique battery-powered radios, but how to power them is a real problem. Many classic radios operated on batteries only, and in many cases a series of three batteries for each radio were required!



The new ABCE1 Battery Eliminator gives you an easy way to replace all these batteries with a simple household AC power connection and resurrect your vintage antique radios! Provides "A" filament, "B" plate, and "C" control grid supplies, which are all isolated from each other. Complete with aluminum case. Runs on 110-240VAC.

ABCE1 Vintage Radio Battery Elim Kit \$199.95

Digital Message System

The third generation of Ramsey digital voice storage kits! We started with the latest digital voice storage technology. It provides up to 8 minutes of digital storage at a frequency response up to 3.5 KHz. (Total message time and frequency response is dependant on selected internal sampling rate.) Once recorded, messages are available for playback on-demand or automatic continuous looping. Standard RCA unbalanced line level output is provided for easy connection to any amplifier, amplified speaker, mixer, or sound system. In addition, a standard 4-8 ohm speaker output is provided to directly drive a monitor speaker. Can be remote controlled via 3-wire BCD with our interface options. Check www.ramseykits.com for all options!



DVMS8 Digital Voice Message 8Ch Kit \$99.95
DVMS8WT Assembled DVMS8 \$149.95

Ultimate 555 Timers

This new series builds on the classic UT5 kit, but takes it to a whole new level! You can configure it on the fly with easy-to-use jumper settings, drive relays, and directly interface all timer functions with onboard controls or external signals.



All connections are easily made through terminal blocks. Plus, we've replaced the ceramic capacitor of other timer kits with a Mylar capacitor which keeps your timings stable over a much wider range of voltages! Available in through hole or surface mount versions! Visit www.ramseykits.com for version details.

UT5A Through Hole 555 Timer/Osc Kit \$24.95
UT5AS SMT 555 Timer/Osc Kit \$26.95

Passive Aircraft Monitor

The hit of the decade! Our patented receiver hears the entire aircraft band without any tuning! Passive design has no LO, therefore can be used on board aircraft! Perfect for airshows, hears the active traffic as it happens! Available kit or factory assembled.



ABM1 Passive Aircraft Receiver Kit \$89.95

Voice Activated Switch

Voice activated (VOX) provides a switched output when it hears a sound. Great for a hands free PTT switch or to turn on a recorder or light! Directly switches relays or low voltage loads up to 100mA. Runs on 6-12 VDC.



VS1 Voice Switch Kit \$9.95

OBDII CarChip Pro

The incredible OBDII plug-in monitor that has everyone talking! Once plugged into your vehicle it monitors up to 300 hours of trip data, from speed, braking, acceleration, RPM and a whole lot more. Reads and resets your check engine light, and more!



8226 CarChip Pro OBDII Monitor-Asmb \$99.95

RF Preamplifier

The famous RF preamp that's been written up in the radio & electronics magazines! This super broadband preamp covers 100 KHz to 1000 MHz! Unconditionally stable gain is greater than 16dB while noise is less than 4dB! 50-75 ohm input. Runs on 12-15 VDC.



SA7 RF Preamp Kit \$19.95

Touch Switch

Touch on, touch off, or momentary touch hold, it's your choice with this little kit! Uses CMOS technology. Actually includes TWO totally separate touch circuits on the board! Drives any low voltage load up to 100mA. Runs on 6-12 VDC.



TS1 Touch Switch Kit \$9.95

Doppler Direction Finder

Track down jammers and hidden transmitters with ease! 22.5 degree bearing indicator with adjustable damping, phase inversion, scan and more. Includes 5 piece antenna kit. Runs on 12VDC vehicle or battery power.



DDF1 Doppler Direction Finder Kit \$169.95

Mad Blaster Warble Alarm

If you need to simply get attention, the "Mad Blaster" is the answer, producing a LOUD ear shattering raucous racket! Super for car and home alarms as well. Drives any speaker. Runs on 9-12VDC.



MB1 Mad Blaster Warble Alarm Kit \$9.95

Laser Light Show

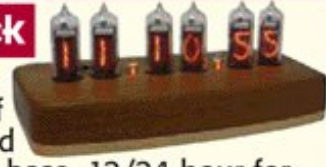
Just like the big concerts, you can impress your friends with your own laser light show! Audio input modulates the laser display to your favorite music! Adjustable pattern & speed. Runs on 6-12VDC.



LLS1 Laser Light Show Kit \$49.95

Retro Nixie Tube Clock

Genuine Nixie tubes popular in the 50's brought back in one of the neatest digital clocks around today! Hand made teak maple base, 12/24 hour format, soft fade-out, auto-dim, and a crystal time base at 20ppm! Tube kits also available.



IN14TM Teak Maple Nixie Clock Kit \$329.95

Water Sensor Alarm

This little \$7 kit can really "bail you out"! Simply mount the alarm where you want to detect water level problems (sump pump)! When the water touches the contacts the alarm goes off! Sensor can even be remotely located. Runs on a standard 9V battery.



MK108 Water Sensor Alarm Kit \$6.95

USB DMX Interface

Control DMX fixtures with your PC via USB! Controls up to 512 DMX channels each with 256 different levels! Uses standard XLR cables. Multiple fixtures can be simply daisy chained. Includes Light Player software for easy control. Runs on USB or 9V power.



K8062 USB DMX Interface Controller Kit \$67.95

HV Plasma Generator

Generate 2" sparks to a handheld screwdriver! Light fluorescent tubes without wires! This plasma generator creates up to 25kV at 20kHz from a solid state circuit! Build plasma bulbs from regular bulbs and more! Runs on 16VAC or 5-24VDC.



PG13 HV Plasma Generator Kit \$64.95

Air Blasting Ion Generator

Generates negative ions along with a hefty blast of fresh air, all without any noise! The steady state DC voltage generates 7.5kV DC negative at 400uA, and that's LOTS of ions! Includes 7 wind tubes for max air! Runs on 12-15VDC.



IG7 Ion Generator Kit \$64.95

Tickle-Stick Shocker

The kit has a pulsing 80 volt tickle output and a mischievous blinking LED. And who can resist a blinking light and an unlabeled switch! Great fun for your desk, "Hey, I told you not to touch!" Runs on 3-6 VDC.



TS4 Tickle Stick Kit \$12.95

Speedy Speed Radar Gun

Our famous Speedy radar gun teaches you doppler effect the fun way! Digital readout displays in MPH, KPH, or FPS. You supply two coffee cans! Runs on 12VDC or our AC125 supply.



SG7 Speed Radar Gun Kit \$69.95

Tri-Field Meter Kit

"See" electrical, magnetic, and RF fields as a graphical LED display on the front panel! Use it to detect these fields in your house, find RF sources, you name it. Featured on CBS's Ghost Whisperer to detect the presence of ghosts! Req's 4 AAA batteries.



TFM3C Tri-Field Meter Kit \$74.95

USB Experimenter's Kit

Get hands-on experience developing USB interfaces! 5 digital inputs, 8 digital outputs, 2 analog I/O's! Includes diagnostic software and DLL for use with Windows based systems. The mystery is solved with this kit!



K8055 USB Experimenter's Kit \$49.95

3-In-1 Multifunction Lab

The handiest item for your bench! Includes a RoHS compliant temp controlled soldering station, digital multimeter, and a regulated lab power supply! All in one small unit for your bench! It can't be beat!



LAB1U 3-In1 Multifunction Solder Lab \$129.95



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- ✓ Christmas Tree Lights
- ✓ Clock Oscillator Schematic
- ✓ Noisy Audio

■ WITH RUSSELL KINCAID

In this column, I answer questions about all aspects of electronics, including computer hardware, software, circuits, electronic theory, troubleshooting, and anything else of interest to the hobbyist. Feel free to participate with your questions, comments, or suggestions. Send all questions and comments to: Q&A@nutsvolts.com

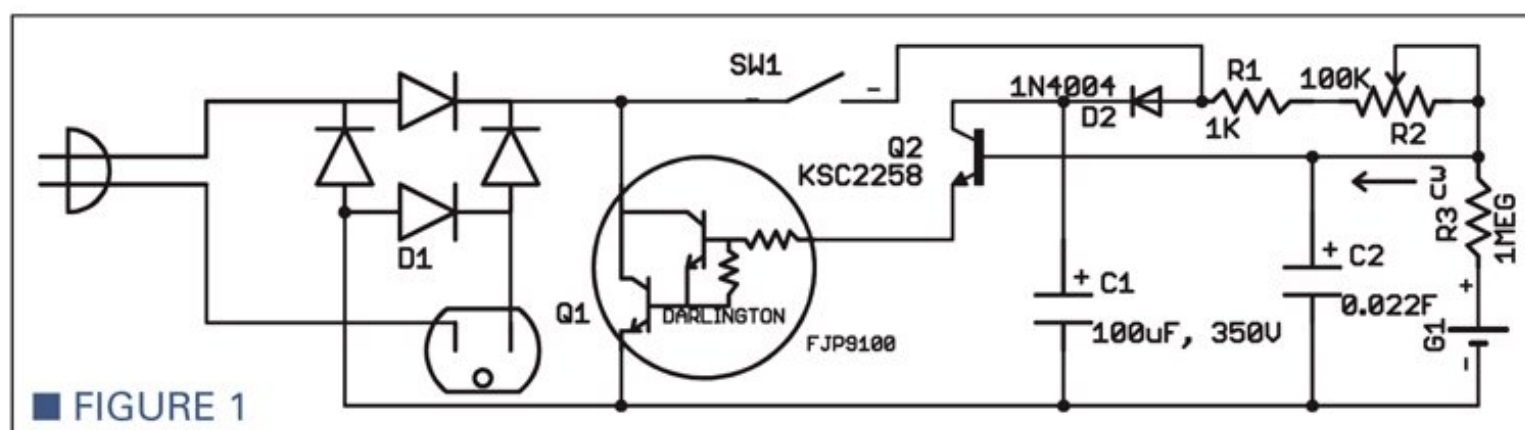
CHRISTMAS TREE LIGHTS

Q I would like to develop or buy a device/circuit that would apply voltage gradually to a string of Christmas tree lights so when a switch is turned on, the lights would light slowly and when turned off they would go off slowly. In model trains, I believe it is called a momentum throttle. An ability to vary the rate would be good.

Thank you in advance for any help you can provide.

— Bob Rymer

A Christmas tree lights can vary from tiny milliwatt bulbs to up to two or three watts per bulb, so I will design for up to 70 watts of power. In the circuit (**Figure 1**), the diode bridge allows the control circuit to operate at DC while AC flows through the load. When SW1 is open, the full 168 peak volts are across Q1 and



■ FIGURE 1

there is no current in the load. When SW1 closes, C1 charges to 168 volts; this puts a spike of current in the load (probably not noticeable). C2 gradually charges through R1 and R2, slowly turning on Q1. The AAA battery, G1, puts an initial charge on C2 so you don't have to wait until it charges up to the Vbe of the transistors. C2 is a super cap; values up to one farad are available if you want an even longer delay. The turn-on time is adjustable from less than one second to about five seconds via R2. The turn-off time is determined by the current draw of Q2 and is not easily varied. The turn-off time is expected to be about five seconds, according to my simulation. **Figure 2**

is the parts list.

PHASE LOCK LOOP

Q Could you explain the basics of phase locked loops? The example

that interests me most is the FM demodulator, such as the LM565. I have seen basic circuits like that before on the web or in books, but could you explain where the equations come from? Is it common to treat these chips as black boxes and just use the equations from the datasheet? Is it simple or are the equations fairly complex to derive?

A I believe Z transforms are needed to really analyze a PLL but I know nothing about that, so I use standard linear analysis which only goes so far. The following is from an article that I wrote which has not previously been published.

There are two types of phase lock loops (PLL). Type 1 uses a passive filter and type 2 uses an operational integrator as a filter.

The type 2 PLL consists of: mixer or demodulator; integrator; and oscillator, as shown in **Figure 3**. This type has zero phase error in the steady state and is useful for recovering a pilot tone or carrier frequency.

The type 1 PLL consists of: mixer or demodulator, low pass filter, and oscillator, also shown in **Figure 3**. This

TURN ON/TURN OFF DIMMER PARTS LIST

PART	DESCRIPTION	PART #
D1	1 amp, 400V bridge	512-DF04M
D2	1 amp, 400V diode	512-1N4004
Q1	3 amp, 275V NPN Darlington	512-FJP9100TU
Q2	100 mA, 300V NPN	512-KSC2258ASTU
C1	100 μ F, 250V, aluminum elect.	140-XRL250V100-RC
C2	22,000 μ F, 5.5V supercap	598-EDLSD223V5R5C
G1	1.5V AAA cell **	115432
R1	1K, 1/4W	271-1K-RC
R2	100K potentiometer	31VC501-F

All Mouser.com part numbers except **Jameco.com

■ FIGURE 2

type has phase error that is proportional to the frequency difference and is useful as a frequency discriminator. The LM565 is an example of a type 1 PLL and is covered in detail in National Semiconductor Application Note #46. The application note is heavy on math, so I will try to boil it down to the essentials.

A logic XOR can be a phase detector (mixer). When both inputs are in phase, the output is low; when both inputs are 180 degrees out of phase, the output is high. The DC output after filtering is proportional to the phase angle, being 50% at 90 degrees. Although it is not obvious, the voltage controlled oscillator (VCO) is a phase integrator. When there is a frequency difference between the input signal and the VCO, the phase difference just keeps accumulating. Since the filter at the phase detector output has 90 degrees phase shift above the cutoff frequency, and since the VCO is an integrator which has 90 degrees phase shift, the closed loop will oscillate if there is positive gain at frequencies above the low pass filter cutoff. One solution is to reduce the open loop gain, but that impacts the ability of the loop to follow frequency changes.

For a high performance loop, it will be necessary to put in a phase lead at F2 which is accomplished by a resistor in series with the filter capacitor; $F_2 = 1/(2\pi R_2 C_1)$ — see **Figure 3**. The low pass filter rolls off at 6 dB per octave and the VCO rolls off at 6 dB per octave for a total of 12 dB per octave at frequencies above the filter cutoff. The filter cutoff (F1) is: $F_1 = 1/(2\pi R_1 C_1)$.

An American engineer, Hendrik Bode, discovered that the closed loop can be stable if the open loop is rolling off at 6 dB per octave as it goes through 0 dB. Stability is not guaranteed but improves with a wider frequency range of 6 dB rolloff. The closed loop bandwidth of

the PLL is determined by the 0 dB intercept of the open loop gain. This frequency is designated F0.

The gain of the phase detector can be calculated from its maximum output (V) in volts per radian (there are 2π radians in a cycle), therefore $K_d = V/\pi$. The gain of the low pass filter is one up to the cutoff frequency and -20 dB per decade (= 6 dB per octave) thereafter. The gain of the VCO is in units of radians per second per volt, but the gain is usually measured as: OS = Hz per volt. So, converting Hz to radians per second, $K_o = OS \cdot 2\pi$ and its gain rolls off at -20 dB per decade.

You can solve the problem with a straight edge and semi-log graph paper using a Bode plot. The vertical axis is dB and the horizontal is frequency. Multiplying the gains: $K_{ol} = V \cdot OS \cdot 2$. This is the gain at 0.159 Hz (one radian per second) This establishes a point on the graph at $20 \cdot \log(K_{ol})$ dB and 0.159 Hz. If this is off the paper, just remember it is 20 dB lower at 1.59 Hz and 40 dB lower at 15.9 Hz, etc. Draw a line at -20 dB per decade through one of those points and note where it goes through 0 dB (call it F0). This frequency is the closed loop bandwidth and the low pass filter cutoff frequency (F1) should be above it in order for the loop to be stable. See **Figure 4**. If the closed loop bandwidth is more than you want or need and/or the cutoff frequency (F1) of the

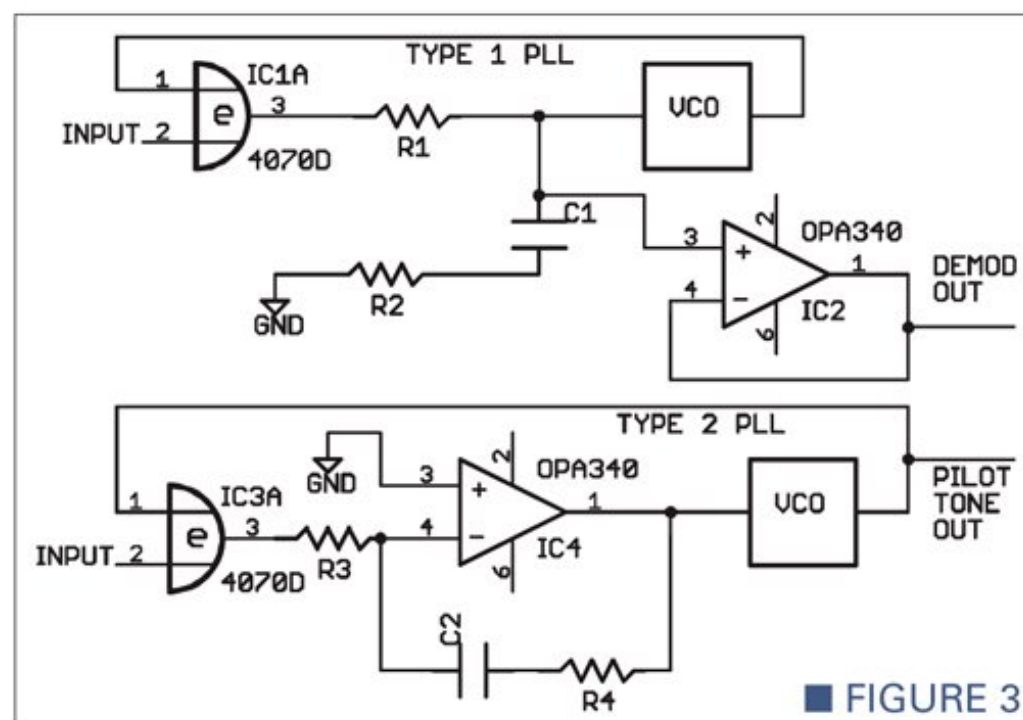


FIGURE 3

low pass filter is too close to the oscillator frequency for effective filtering, then move F1 to a lower frequency (much lower) so you can install a phase lead at F2 that is below the new F0 such that the plot passes through 0 dB at 20 dB per decade. See the dashed line in **Figure 4**.

By following these rules, you should be able to design a PLL with the stability and bandwidth you want.

CLOCK OSCILLATOR SCHEMATIC

Q I have an old sound chip that needs a clock source. Unlike a modern chip that I'm used to, it doesn't have two pins I can straddle a crystal across — rather it has only a single pin. How can I generate a (roughly) 2 MHz clock signal to drive this chip?

— John Calhoun

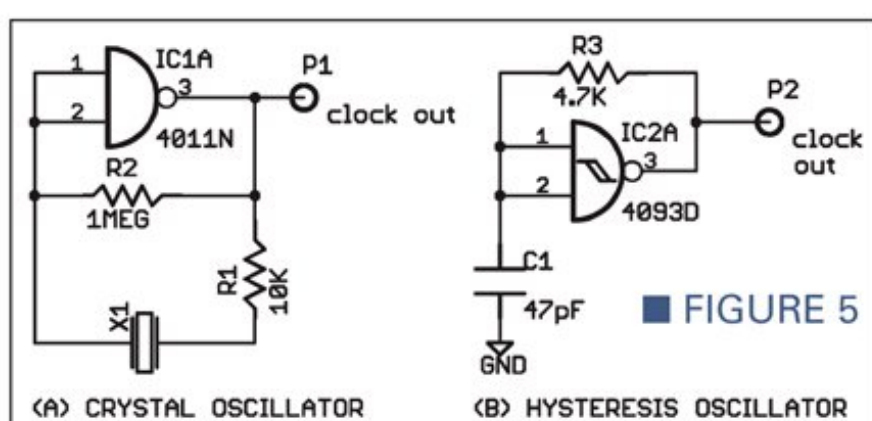


FIGURE 5

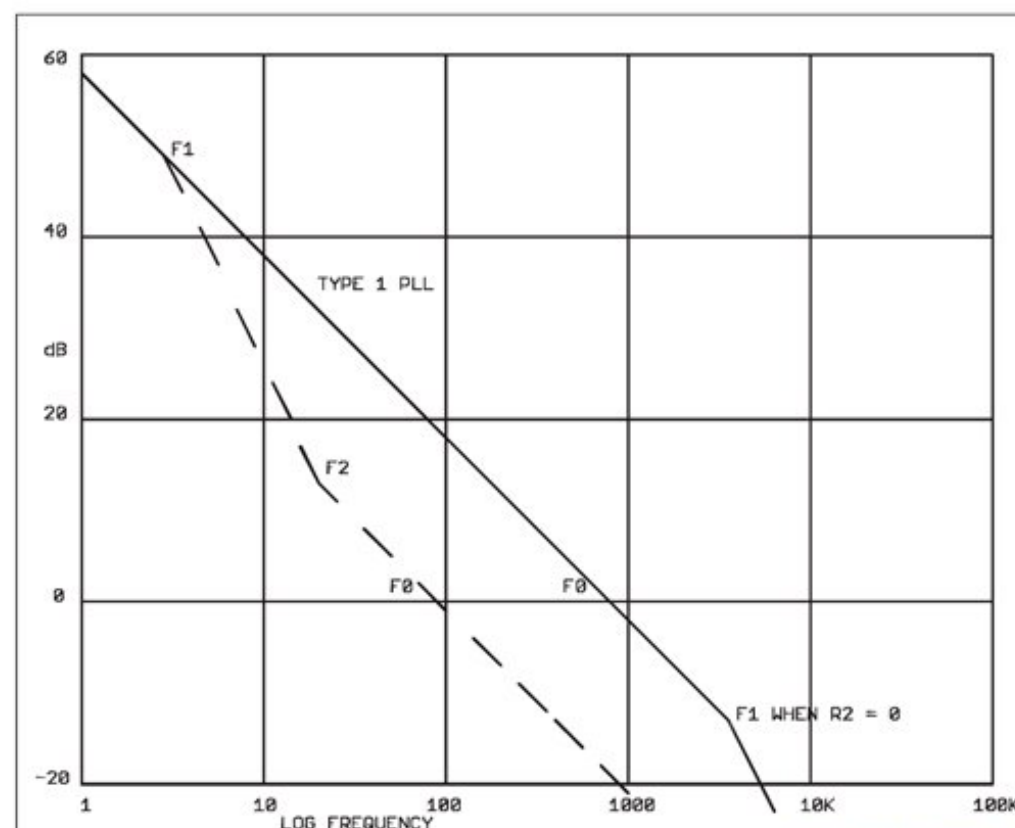


FIGURE 4



A Figure 5 (A) is a crystal oscillator. I used a CD4011 quad two-input NAND but any CMOS inverting gate or buffer should work. R1 limits the crystal current; too much drive could damage it. R2 provides DC bias to keep the gate input in the linear range. I breadboarded the circuit and find that it works okay at nine volts VCC and above, but the frequency is way low at five

volts. Perhaps HCMOS would be better at five volts. If you don't need crystal accuracy, the hysteresis oscillator using a Schmitt-trigger gate will be cheaper; see Figure 5 (B). The hysteresis is not well controlled so you will have to tweak it to get the frequency right. Also, the frequency varies with supply voltage. I breadboarded the circuit and got 2 MHz with 4.7K and 47 pF.

NOISY AUDIO

Q I am a new reader to *Nuts & Volts* and thought of a question that you might be able to help with. My wife and I recently moved into a new home, and I purchased a floor-model Samsung DLP. However, one thing in particular bothers me. It seems to inject a low frequency "noise" into the AC line, which my 10" powered sub dutifully picks up and broadcasts to the annoyance of both myself and my visitors. This hum or drone (depending on your opinion) is very noticable, and only goes away when the TV is turned off or the sub is unplugged — neither of which enhances the full theatrical effect.

My Rotel pre-amp and amplifier seem to be completely immune to the noise. I can't hear it at all from my bookshelf speakers. This leads me to believe that either a) my inexpensive powered sub wasn't really worth getting; or b) the sub (or TV) could use a power-line filter.

Do you think such a thing would be worthwhile? I enjoy working with electronics and would be willing to try making a circuit to provide "conditioning" if practical. However, I haven't got much experience in dealing with mains voltage or designing notch filters. For that matter, I'm not even sure if I would know how to go about identifying the specific frequencies being injected by the TV. Any advice or guidance you would be willing to share is certainly appreciated!

— David Passarelli

A I suspect the problem is caused by the fact that your equipment is plugged into different AC outlets and the safety grounds are at different AC potential. Try plugging the TV and sub into the same outlet. If you're already doing that, then you have a ground loop formed probably by the coax cables that connect the system. Make sure the grounds don't close on themselves and make a loop. If you're still having issues, send me a diagram of the system. **NV**

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6' output cord with 2.1mm coax power plug, center positive. Detachable IEC input power cord included. cULus, FCC, CE.

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10 for \$18.00 each

\$19⁰⁰ each



MINI-MOTOR, VIBRATOR

Tiny motor with offset weighted shaft. Designed to vibrate in mobile communications devices. Operate on 1.5-4.5Vdc. Rubber casing covers motor, but is easily removable. 15mm - length including shaft. 4mm diameter without rubber. Rubber casing is 5 x 6.5 x 11mm. Gold contacts.

CAT# DCM-371

10 for \$1.10 each • 100 for 95¢ each

\$1²⁵ each



SUPER BRIGHT RED, SUPERFLUX LED

LiteOn Piranha# LTL912SEKSA. Ultra-bright Red Super-flux LED. 7.62mm square, 4-pin DIP package aids heat dissipation. Designed for high-current, high-flux output. Wide viewing angle.

CAT# LED-912

65¢ each

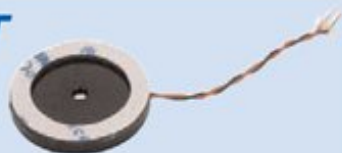


PIEZO ELEMENT

0.86" diameter x 0.1" plastic housing with a ring of self-adhesive neoprene padding on the front face. 1.25" long leads. 0.79" diameter piezo element can be removed from case.

CAT# PE-49

75¢ each



10 for 65¢ each • 100 for 50¢ each

GADGET SACK

Digital Concepts # GB-101. Multi-purpose drawstring carrying pouch. Stores all of your accessories and devices. Side compartments for added storage and protection. Ballistic nylon exterior; soft, padded interior. 4" x 6" x 8".

CAT# CSE-85

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12 VDC 58 RPM MINI-MOTOR

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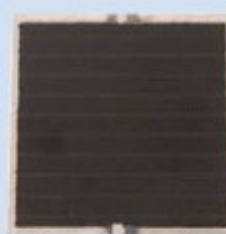
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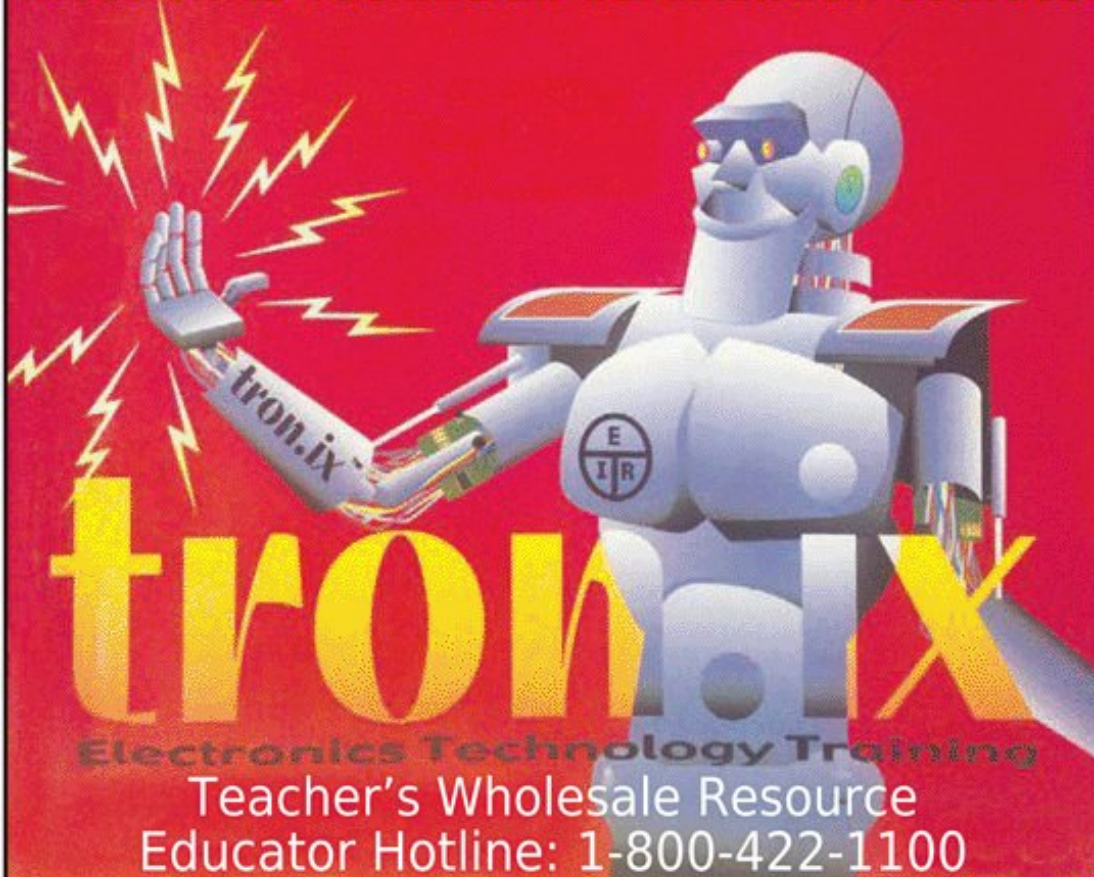
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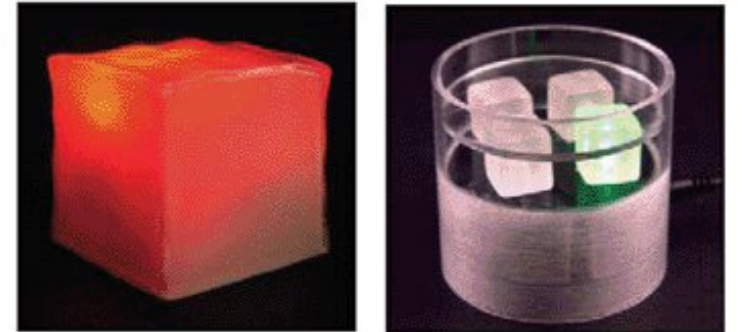
ESP LAMP CIRCUIT

Images SI, Inc.'s new ESP lamp circuit provides

several fertile areas of cutting edge research for users to dabble in, such as influencing quantum probability of decaying radioactive particles and detecting the particles on the machines. The ESP lamp can be used for entertainment/testing various aspects of ESP/PSI, precognition, telepathy, and psychokinesis (PK).

The ESP lamp contains a miniature Geiger counter to generate true random numbers that light one of four different color LEDs so it functions as a truly random mood lamp with a very high coolness factor.

The ESP lamp is offered in a round or cube version, and as a kit or assembled and tested. Price for the ESP lamp kit is \$149.95; assembled is \$199.95.



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Continued on page 77

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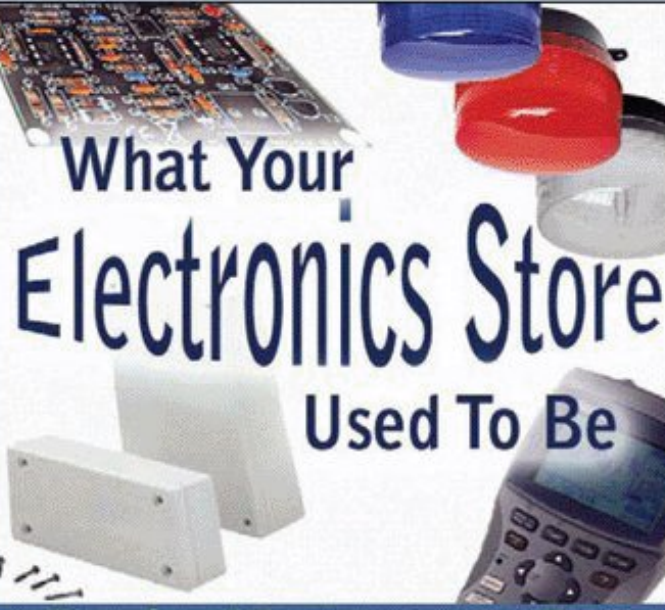
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WHAT A POTENTIOMETER DOES

This potentiometer is being used as a rheostat or variable resistor. Its function is to vary the resistance in electronic circuits and devices. For example, they are used in radios and TVs to control the volume of the audio in the speaker. A "pot" can also be used as a voltage divider. By doing this experiment, you will see that a potentiometer can vary the resistance in a circuit and, in this case, the brightness of the LED.

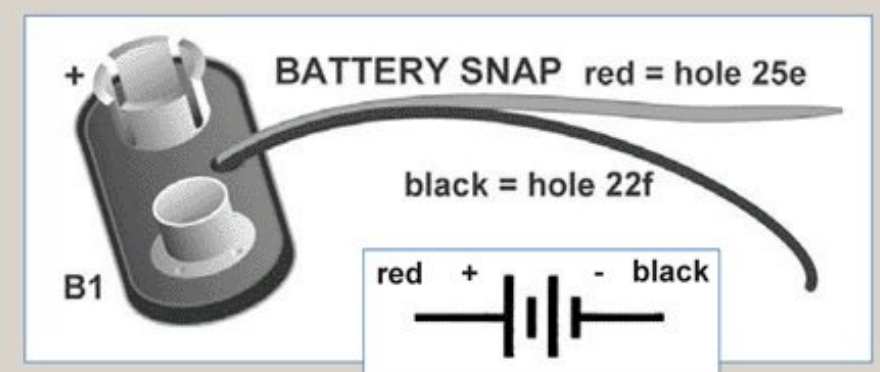
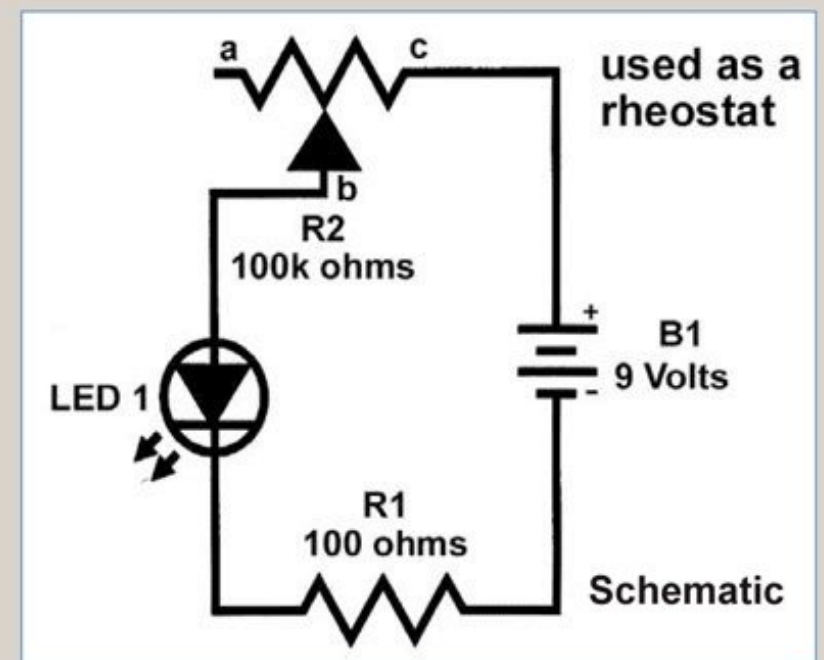
1. Build the Circuit.

Using the schematic along with the pictorial diagram, place the components on a solderless breadboard as shown. Verify that your wiring is correct.

2. Do the Experiment.

Theory: This electronic circuit consists of an LED, a 100 ohm resistor (to keep the LEDs from burning out from too much current when the potentiometer is adjusted to zero ohms), a nine-volt battery, and a potentiometer. The electrons flow from the battery through the resistor, through the LED, through the potentiometer, and back to the battery. The higher the resistance in the circuit, the fewer the electrons that will flow.


Procedure: Connect a nine-volt battery to the battery snap and observe the brightness of the LED. Now, turn the shaft fully clockwise and then fully counter-clockwise. As you turn the shaft, the resistance varies through the potentiometer and this will cause the LED to get brighter and dimmer.



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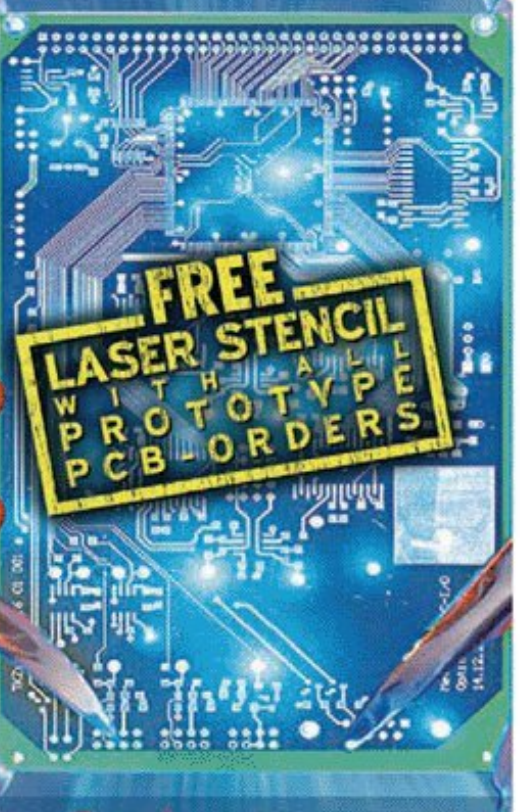
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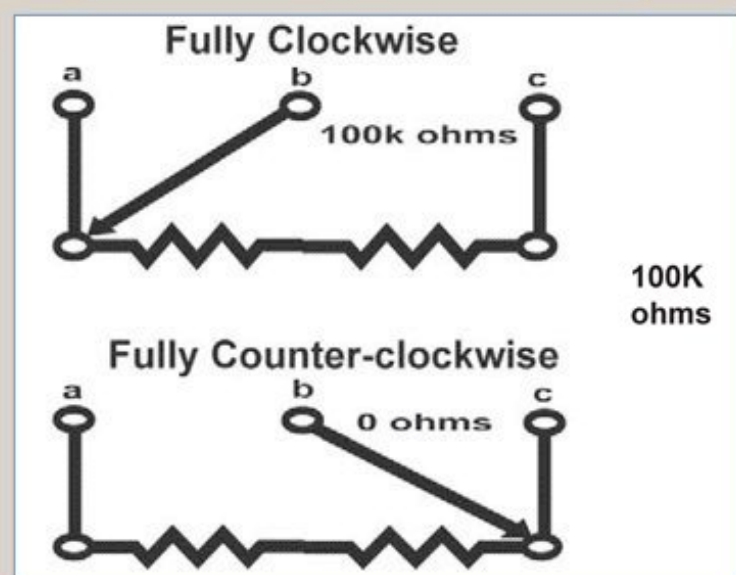
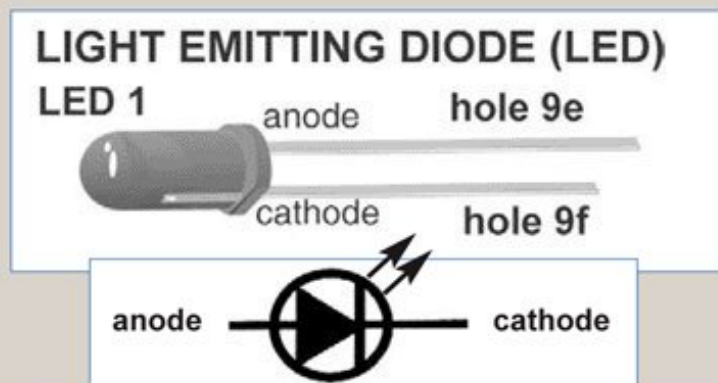
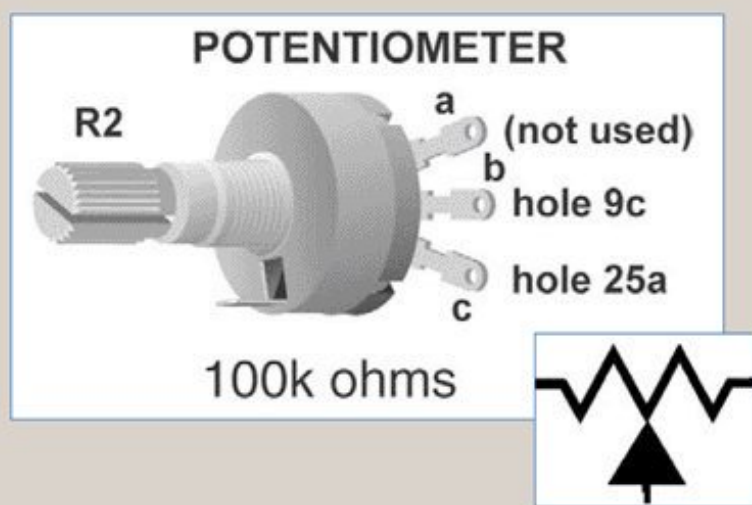
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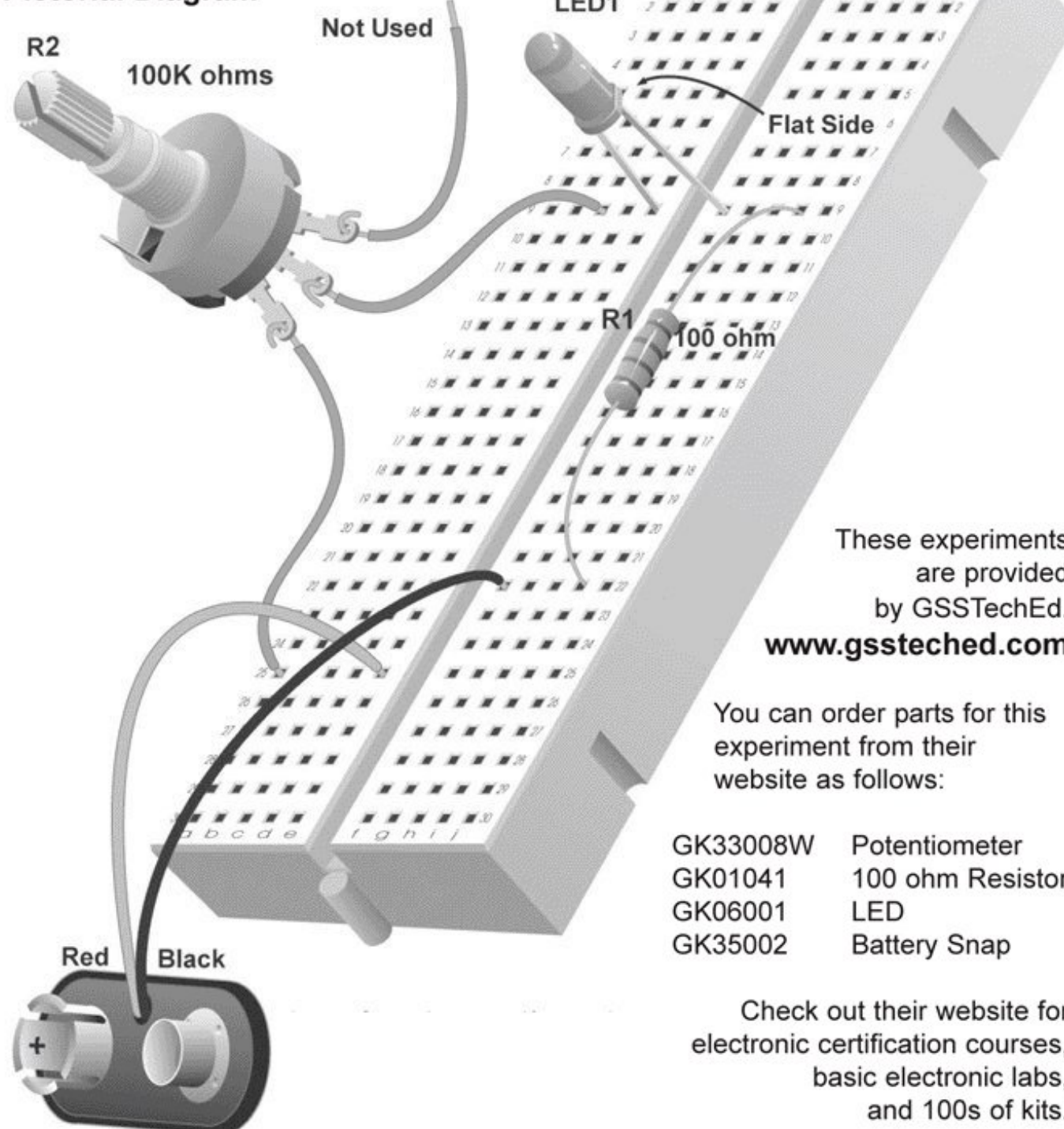
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Beta
LAYOUT



Pictorial Diagram



These experiments are provided by GSSTechEd.
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You can order parts for this experiment from their website as follows:

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GK01041	100 ohm Resistor
GK06001	LED
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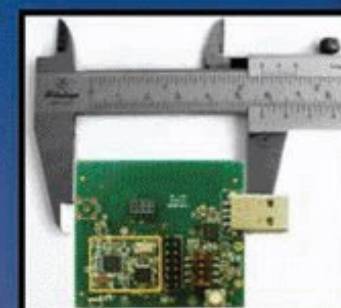
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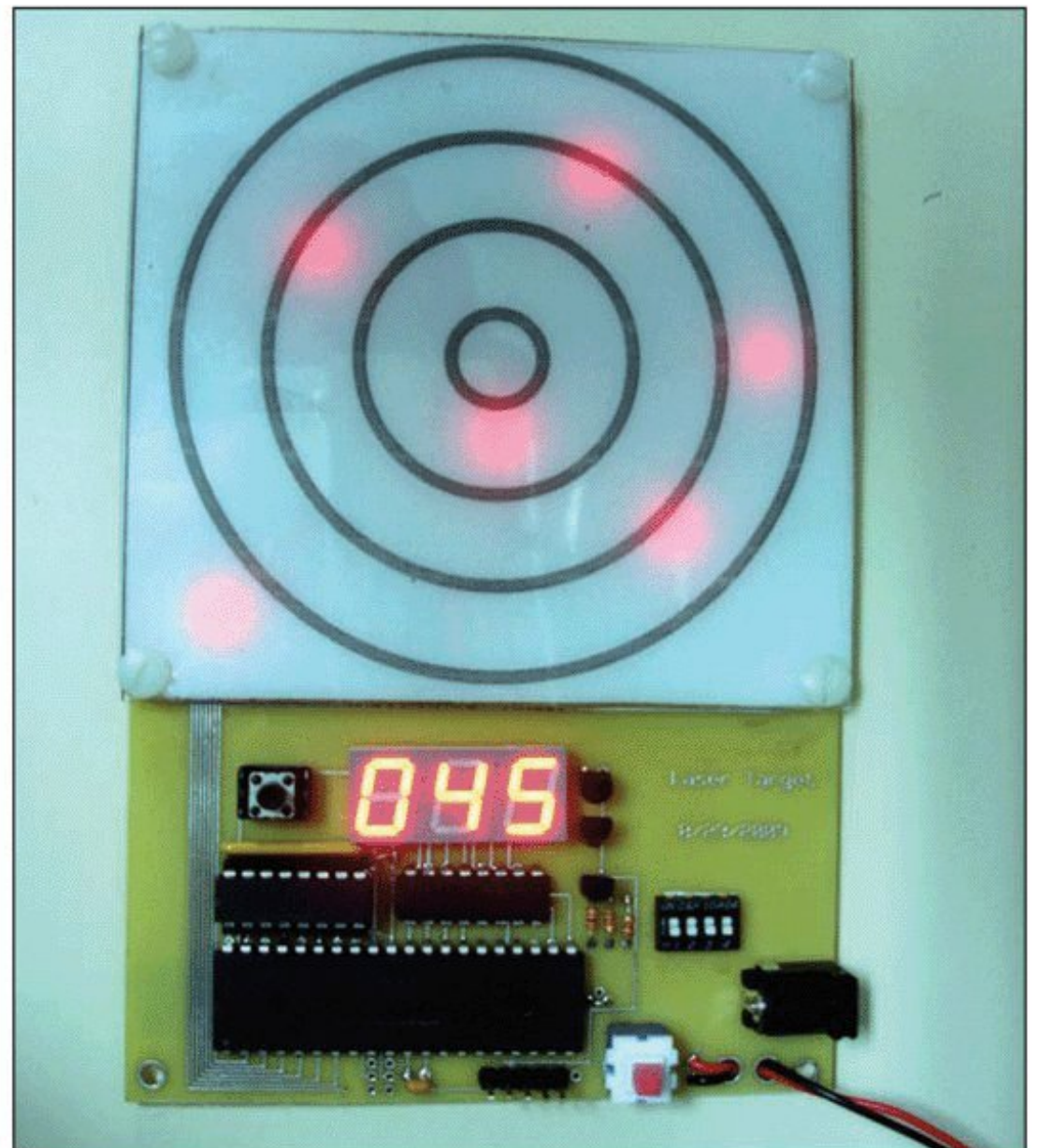
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With ammunition in seemingly short supply and the need to keep my shooting skills proficient, dry firing helps control, but does not improve your accuracy. I decided to build an indoor shooting range using my own weapon. There are setups available for about \$500 which was a little too much for my budget. I built my shooting range for about \$100.



This laser system can be built for use with any pistol 9 mm and above. A plastic tube is used to house the laser, sensing board, switch, and batteries. The tube slides down the barrel of the gun. When it detects the click of the hammer, it fires the laser. Although it is 3" in length, it can be used in guns with 1" barrels.

The target runs off of four AA batteries (or a battery eliminator). It keeps score and lights up where the photon bullets hit.

I consider this an advanced project. It will take about four to six hours to build.

■ FIGURE 2.

By the time you finish, you will definitely know how to solder surface-mount components. There are 196 small photodiodes and 49 small LEDs. I would build the target first, then prepare the small laser printed circuit board (PCB).

On Target

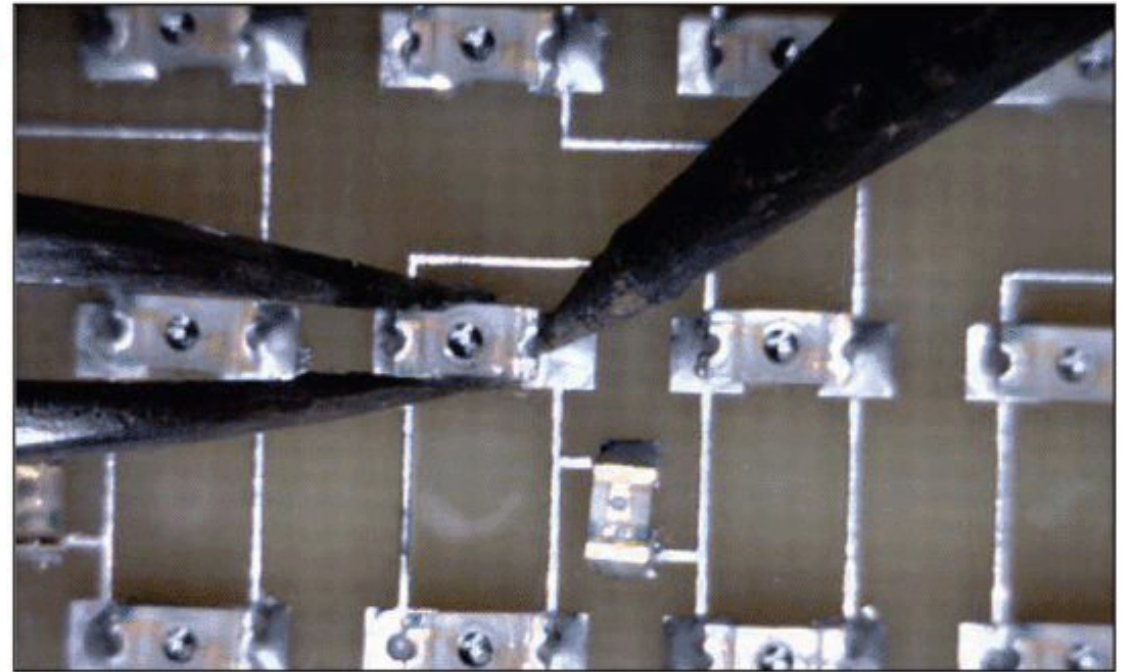
The target measures 3.5" x 3.5" and uses photodiodes to detect the laser. The laser has a 6 mm spot at 40 meters. In a nutshell, a 1/2" square uses four photodiodes which are placed apart and electrically connected in parallel. An LED is located in the center. A grid is set up using seven rows x seven columns, or 49 sets of diodes. The 3/16" clear red plastic allows the red laser to penetrate and blocks most of the ambient light. The .01 mm thick white translucent piece of plastic causes the laser to diffuse and trigger the photodiodes (see **Figure 1**).

A Microchip PIC16F917 is a 40-pin microcontroller. It has 25 inputs and output ports. Sixteen of these ports are used to detect the laser pulse by multiplexing the photodiodes. Once the hit is determined, they turn on an LED indicating where the hit was. Eight of the other ports are used to multiplex a three-digit display. The seven-segment display shows the accumulated points.

When light strikes a photodiode, it conducts electricity. The collectors are biased to Vcc using a 3.3K SIP (Single Inline Package). The 3.3K SIP used in this project has eight pins and seven 3.3 resistors (bussed), all connected to a single source. There are seven rows and seven columns as mentioned previously. The outputs of the rows are multiplexed using port B and the collectors are multiplexed to ground using port A. In the center of each square is an LED whose polarity is reversed across the photodiodes. The microcontroller runs at 20 MHz and scans the 49 squares in 68 microseconds. When a hit is detected, the microcontroller stops the scanning. It turns on the LED in the square where the hit was detected by reversing the polarity of the column and row. It determines the points in the area of the hit and adds them to the score. The hit and score stay lit for five seconds and then the unit starts scanning again. The score can be reset by pushing a reset button. This is connected to the MCLR (master reset) of the microcontroller.

It can be powered by four AA, C, or D batteries, or a five volt power supply can be used. A jack is provided for the power input.

The three seven-segment displays



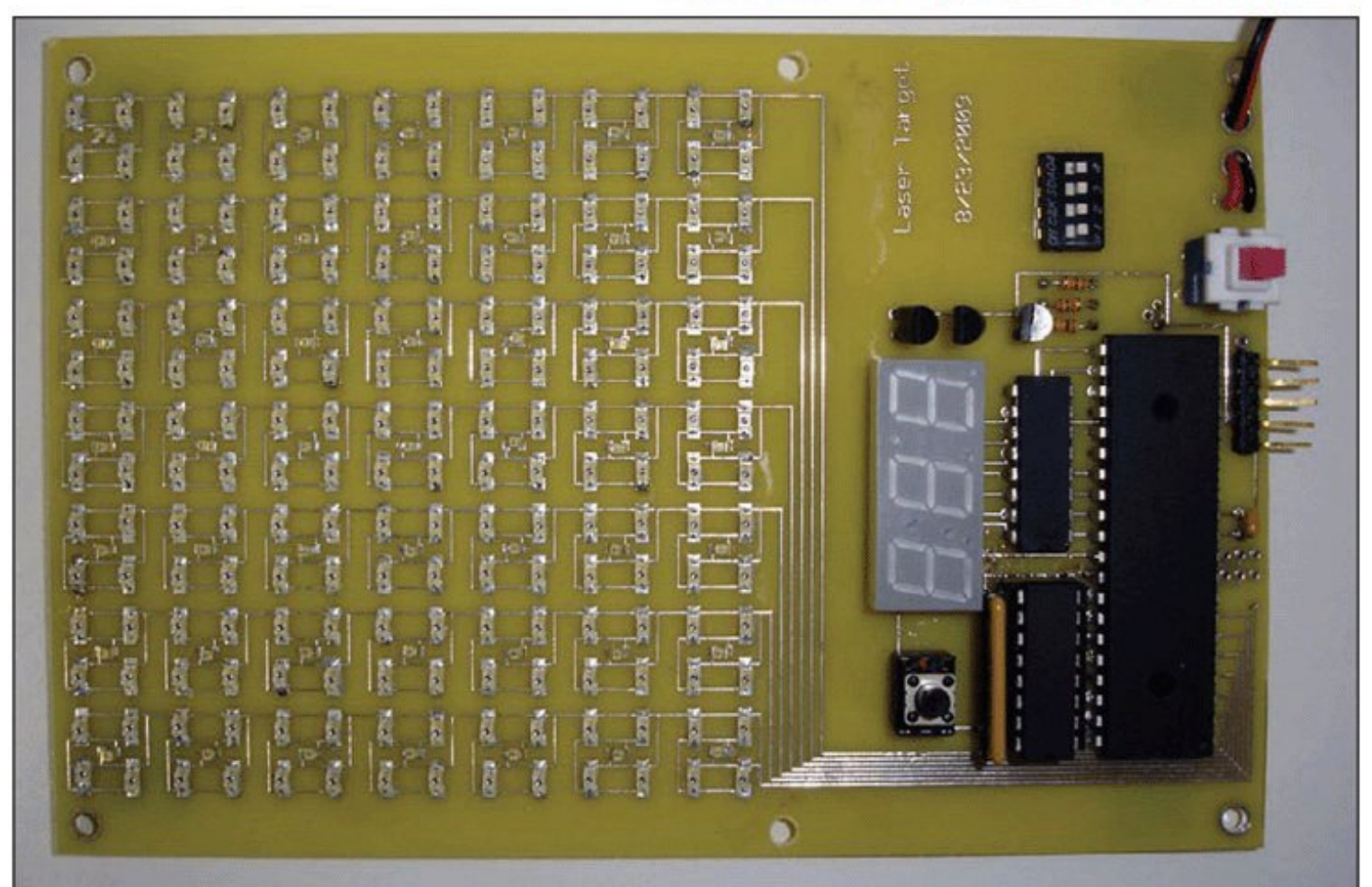
are common anode and are multiplexed using three PNP transistors. The grounding of the cathodes is performed via eight 470 ohm resistors going to port D. The 470 ohm resistors are in a network which is similar to a SIP; however, they are contained in a DIP (Dual Inline Pin) and are not connected to each other. There is a DIP switch which can change the display for testing, slow fire, rapid fire, or your own program. (Up to eight programs are available that will be discussed later.)

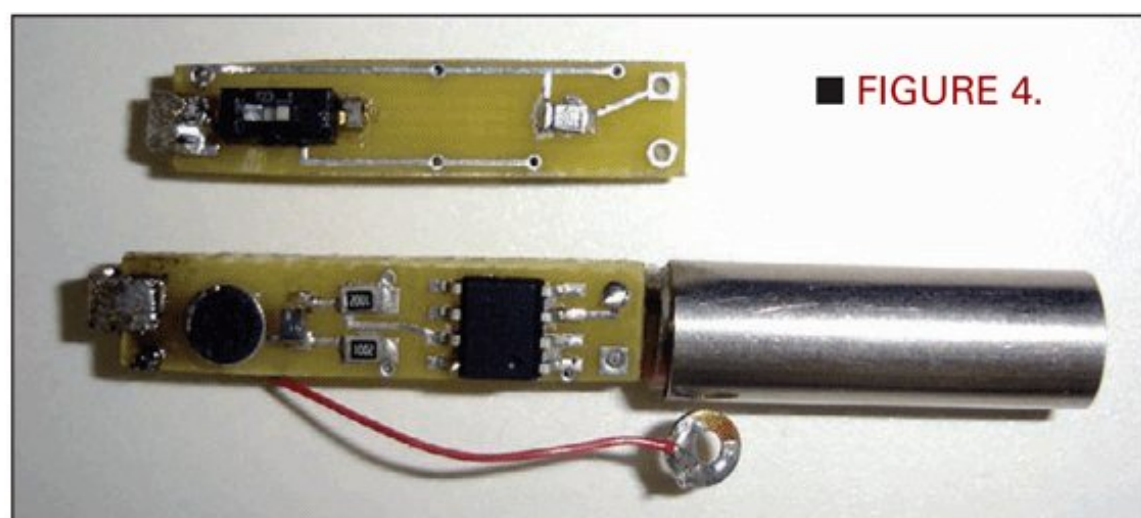
Building the Target

Because of the small surface-mount photodiodes and LEDs, use a small tip soldering iron and magnifier (see **Figure 2**). Place the four feet on the bottom side of the board next to the mounting holes. This will prevent scratching the traces and keep the board from sliding when soldering.

Solder the photodiodes and the LEDs to the board. The photodiode's marker dots (collector) face to the left; the LED cathodes all face down and are also marked with

■ FIGURE 3. The target printed circuit board.





■ FIGURE 4.

dots. You can use fine solder but I found it was easier to use a solder paste. Put one small dab on each pad (don't use too much). Using curved forceps, pick up a photodiode and place it on the pad. Touch the pad with a

small soldering iron. I recommend soldering one pad on each diode and then inspecting it with a magnifier to make sure the dots are correct. It's easy to remove one if reversed. However, if both sides are soldered you almost need a surface-mount removal soldering iron. Perform the same procedure using the LEDs.

Solder the power jack and the .01 μ F cap to the board. If you want to use batteries, there is a mounting hole for the wire and pads for soldering. Solder in the DIP switch.

Next, solder the microcontroller, two 470 ohm networks, and the SIP. The SIP sets the sensitivity of the target for ambient light. I found 3.3K worked best. The higher the resistance, the more sensitive the target becomes to light. Please note that the square pads

indicate pin 1 (watch the SIP position). Solder the three PNP transistors (flat side points to the top), the three 10K 1/8 watt resistors, and the reset switch. Solder the six headers. The microcontroller can be programmed on the board using the six-pin header and a Microchip PICKIT 2 available in the *Nuts & Volts* webstore at www.nutsvolts.com.

The programming files are also located on the *Nuts & Volts* website, along with all the necessary files to complete this project.

Testing the Target

To test the board, I use a laser pointer. Connect the power and turn on the target. A bar should be displayed indicating that the power is on. Set the DIP switch on test. Press the reset switch. Using a laser, light one of the four diodes in column one, row one. Each hit on the diode will flash the LED in the center. Perform this procedure in each of the 49 squares, testing all 196 photodiodes. This test is to make sure all the photodiodes and LEDs have been properly installed.

Final Assembly

The target can be printed on styrene using a laser printer. (The target diagram is in a Word document on the *Nuts & Volts* website.) Make another copy on

BILL OF MATERIALS

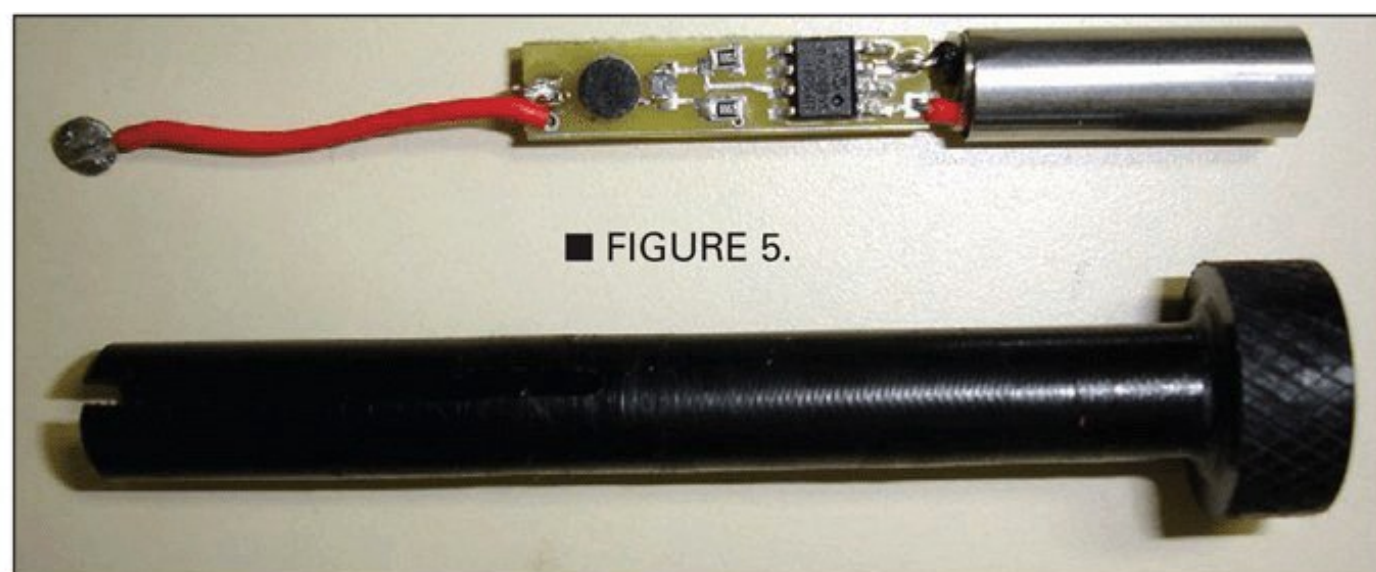
ITEM	DESCRIPTION	QTY	MANUFACTURER/PART #
TARGET:			
IC1	Microcontroller	1	Microchip/PIC16F917-I/P
Battery Holder	4AA w/switch	1	Eagle/12BH348/CS-GR
PCB*	4"x 8"	1	
C1	.1 μ F 50 volt	1	
Header	2.54 mm post 2.9x5.84 m	1	
Jack	2.1 mm PCB	1	CUI/PJ-102A
LEDs	Surface-mount (red)	50	Kingbright/AP201SRCPRV
Photodiodes	Surface-mount	200	Everlight/EL-PT11-21C/41TR8
Q1-3	2N3906	3	
R1-6	10K 1/8 watt	6	
R9	3.3K SIP bussed	1	
S1	DPST 23 mm	1	C&K/PVA1 EE H2
S2	Momentary 6 mm	1	
S3	DIP three positions	1	
Seven-segment Display (three CA)		1	Lite-on-Inc /LTC-4624JR
Miscellaneous:			
Screws Nylon	6-32 x 1/2"	4	
Plexiglas (red)	4"x 4" x 3/16"	1	
Styrene	4"x 4" .01 mm frosted	1	
Feet	1/4"	4	
PHOTON EMITTER:			
IC1	Microcontroller	1	Microchip/PIC12F508-1/SN
PCB*	1		
C1	.01 μ F 16V 805	1	
Laser	Dot 1 mw	1	Quarton, Inc./VLM-650-03-
LPT		1	
Microphone	2.2K ohm x 4 mm	1	Project Unlimited/TOM-
1545P-R			
R1-2	10 K 805 Surface-mount	2	
Microswitch		1	Copal Electronics/CHS-01TB
Miscellaneous:			
Batteries	#10 hearing aid	5	
Brass Washer	#4	1	
Plastic Rod	3" length 5/8" diameter	1	
Set Screws	4-40 1/8"	3	
Set Screw	1/4-20 3/8"	1	

*Printed Circuit Boards and programming chips are available in the *Nuts & Volts* webstore (www.nutsvolts.com). All parts can be obtained through www.mouser.com or www.digikey.com.

Machining the Photon Emitter (Laser)

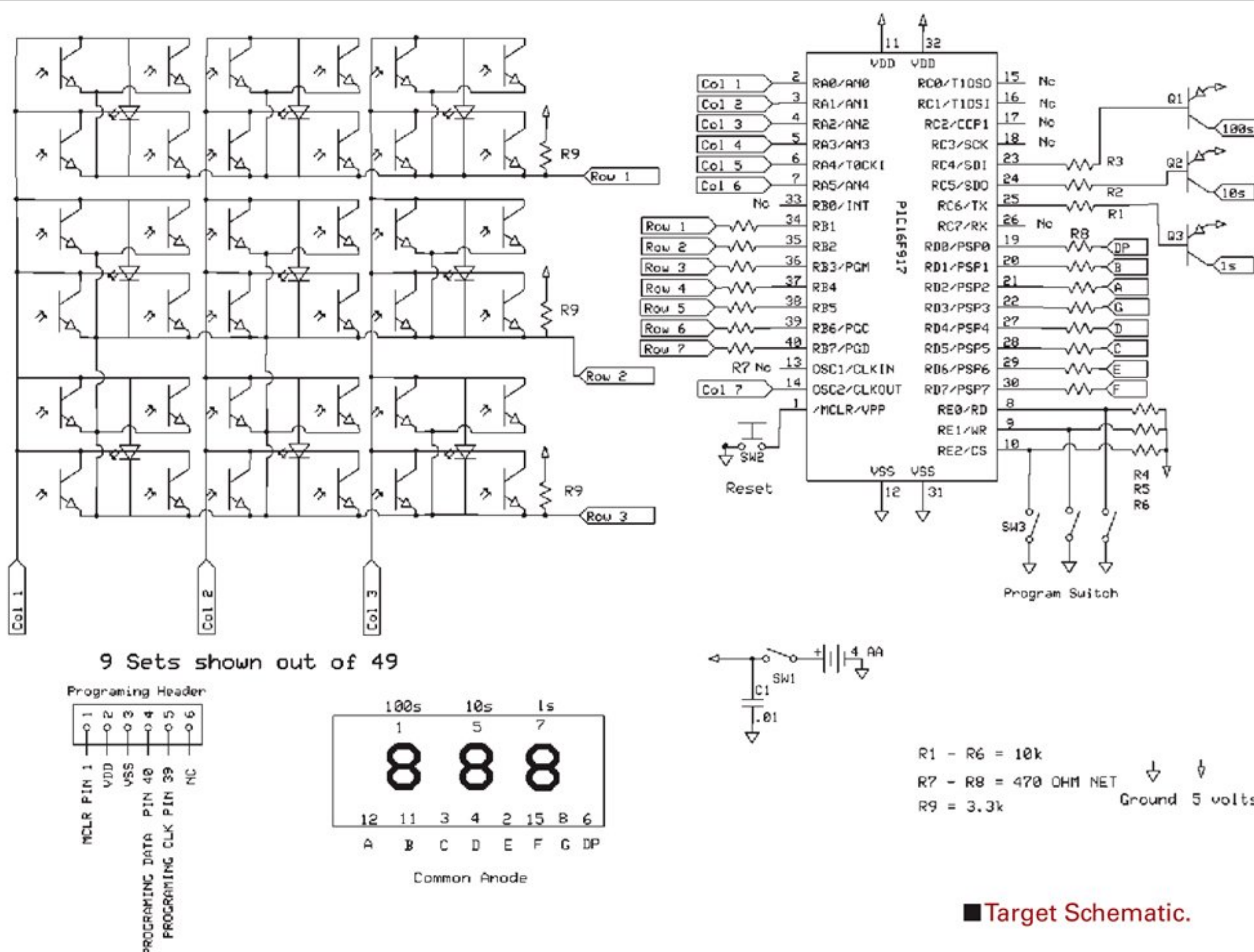
Follow this Method:

1. Knurl 3/8" of one of the ends of the 3" plastic. This will be the end where the laser will go.
2. Center drill both ends.
3. Chuck the tube's knurled end and use a center on



■ FIGURE 5.

- the tailstock on the other end.
4. Turn the tube to the diameter of your gun barrel leaving $3/8"$ of the knurl. The tube should be a snug fit into the barrel.
5. Drill halfway through the tube using a $15/64"$ drill. Reverse the tube and drill from the other side to complete the hole.
6. Chuck the body of the tube with the knurled end flush with the chuck pointing toward the tail stock. Using an "L" drill, drill for two inches.
7. Tap the other end using a $1/4"-20$ for $3/8"$ for the set screw.
8. Using a $1/16"$ mill or Moto tool, cut a slot from the battery end for $1.5"$. This will be a slot for the



■ **Target Schematic.**



■ FIGURE 6.

positive wire going to the last battery and to access the switch.

9. Drill three #43 holes at 120 degrees 1/8" from the end of the knurled end and tap with a 4-40 tap. Place three 1/8" 4-40 set screws into the tapped holes.
10. Using electrical tape, wrap the last 1/8" to 1/16" of the proximal end of the laser. This will act as a pivot. It can also act as a shim by cutting part of the tape off.

One of the problems I encountered was that if I either

TOOLS NEEDED

Lathe
Mill or drill press
Knurling tool
Soldering pencil
Magnifier
Curved forceps

#43 Drill
15/64" Drill
"L" Drill
1/16" End Mill
4-40 Tap
6-32 Tap
1/4-20 Tap

bored or drilled the hole for the laser, it was still off from the sights. I discovered that this was due to the laser manufacturing alignment itself. I decided to add an adjustment.

Laser Electronics

The photon emitter uses an inexpensive laser diode (<\$10) which is powered by five #10 hearing aid batteries. The detection circuit uses a sub-miniature microphone. When the trigger is pulled, the firing pin causes a click that the microphone picks up. Its output feeds into a PIC12F508 which then pulses the laser for 50 milliseconds. R3 limits the laser's output. This prevents lock-up. The whole detection system is soldered to a 1" x .225" board (see **Figure 4**).

Solder the microcontroller to the board noting pin 1, the two 10K resistors, and the .01 capacitor. The microphone is soldered from the top of the board to the square pin with pin 1. Cut the speaker leads short and file or sand so than you can mount the switch to the back of the board. R3 is soldered to the back of the board along with the micro-switch. Using a piece of 1/4" solder braid, fill with solder and bend at a 90 degree angle. Solder this braid to the top and bottom square pads next to the microphone. This will act as the negative contact for the batteries. Carefully cut the wires from the laser to about 3/8" and strip. Solder the red wire from the laser to the square pad next to the chip. Solder the black wire to the round hole. Using a 1" piece of red wire wrap, solder it to the pad next to the solder braid. With the slot and the switch up, thread the wire, board, and the laser from the knurled end. The laser should be flush to the end of the tube. Tighten the Allen screws. The red wire runs along the slot. Trim the red wire to the end of the tube and solder the small brass washer to it (see **Figure 5**). The switch should be visible.

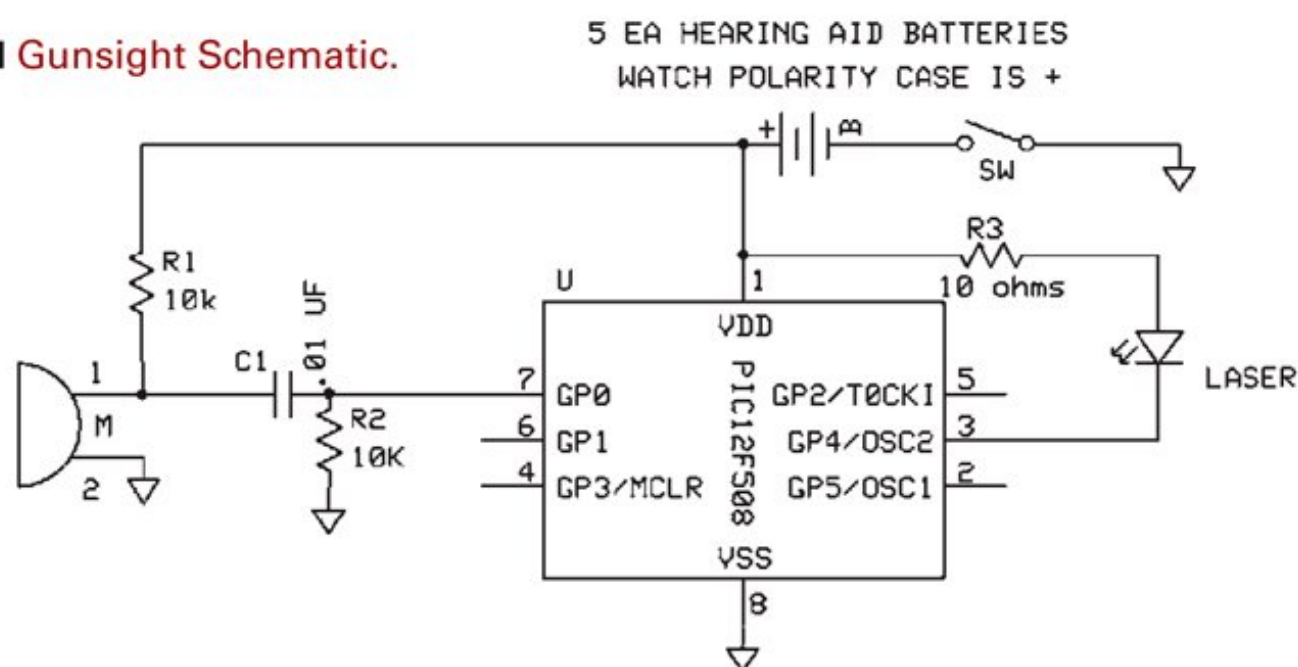
Use a spring from a ball point pen and cut to a length of 1/4". Place five batteries into the tube with their negative ends toward the board. Put the washer on the last battery, add the spring, and screw the set screw into the tube. Turn on the switch and tap the tube on the table. The LED should pulse on and off.

The microcontroller goes to sleep and wakes up when it detects the click. However, the two 10K resistors will pull 250 uA. The batteries produce 75 mAh. However, when the laser fires it pulls about 25 mAh for 50 milliseconds.

Testing the Laser Alignment

Insert the laser tube into the barrel of the gun. The knurled end should be flush

■ Gunsight Schematic.



with the end of the barrel (see **Figure 6**). Cock the weapon and fire at a blank white wall. Twist the tube for the best alignment. Using an Allen wrench, adjust the three screws until the beam aligns with the sight. Put a drop of white paint or nail polish on top of the tube for relocation the next time.

Using the Laser Sight and Target

There are four programs available:

1. **Test.** (DIP switch one on, two and three off).
2. **Normal.** Displays a hit and the score for five seconds (DIP switch one and two are on three is off).
3. **Rapid fire.** Turns on the LED, and keeps them on (DIP switch one, two and three on).
4. **Design your own programs.** (Five more DIP switch settings are available).

Turn on the switch and load the photon tube into your barrel.

Work in a semi-lighted room. *If it is too bright, it can lock up the target.* Place the target on the wall about 25 feet and turn it on. Set the program you are going to use and press reset. With an automatic weapon, you will need to recycle the breach each time. In the normal mode, the hit will display for the five seconds and the score will accumulate with each shot. Press the reset button to clear.

The Rapid Fire mode will display the number of shots. At the end of six shots, the LEDs will light and the score will display. Again, press the reset button to clear. (Note: If two shots hit the same location, only one will be displayed, but the score will be correct.)

Think Safety First!!

Remember these tips:

- Don't dry fire with children around.
- Remove all ammunition and place it away from the practice area.

- Double-check the chamber!! After checking that your weapon is clear of all ammunition, dry fire into a safe back-stop, for example a brick fireplace.
- Always check to see that the laser is removed from the barrel before live firing!!

I hope you enjoy this project and always stay on target! **NV**

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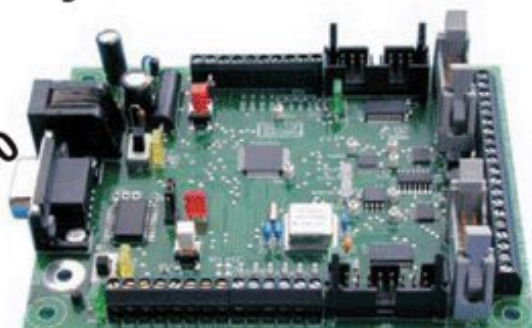
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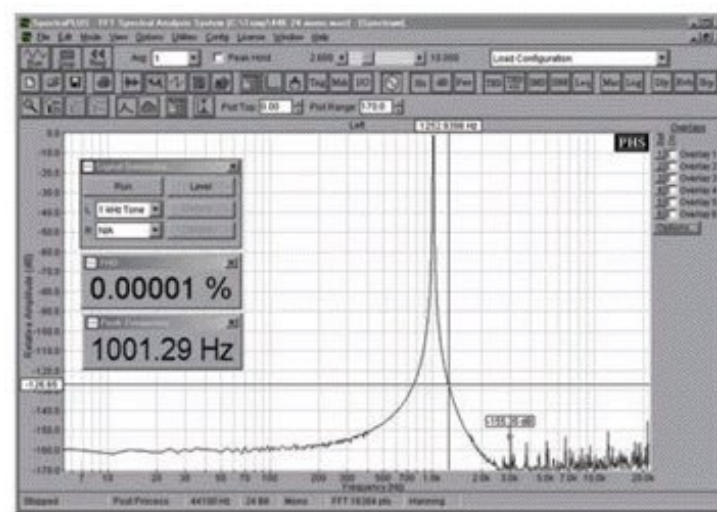
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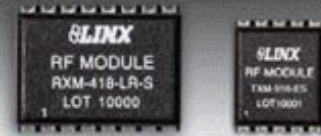
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BY DAVID WILLIAMS

BUILD A JUMBO LED

DIGITAL THERMOMETER



Anyone with a tropical fish tank knows that the water temperature must be maintained within a relatively narrow temperature band – typically around 25°C (or 77°F), depending on the type of fish. In most home aquariums, this is achieved using a thermostatic heater. When the temperature drops below a preset level the heater switches on, and when it rises above a higher preset, it switches off.

Many aquariums are also equipped with a thermometer, but it can often be difficult to see or read accurately. This project was born from the need to easily check the water temperature at a glance. It features three 2.2" large LED digits that are easy to read from across the room and a precision DS1822 temperature sensor. Temperatures can be selected to display in Centigrade, as well as Fahrenheit.

The DS1822 is a direct-to-digital temperature sensor with $\pm 2^\circ\text{C}$ accuracy over a -10°C to $+85^\circ\text{C}$ range. It is presented in a compact TO-92 package and transmits digital temperature readings using only three wires. It is easy to encapsulate the DS1822 in silicon or epoxy for a robust and waterproof sensor that makes it perfect for this project.

Of course, a digital thermometer with a large LED readout and a remote temperature probe is not just limited to aquarium owners. This project will appeal to anyone that wants accurate digital temperature measurements.

Home beer brewers, hydroponic gardeners, amateur weather watchers, or folks just interested in energy management will all find this to be a very useful device.

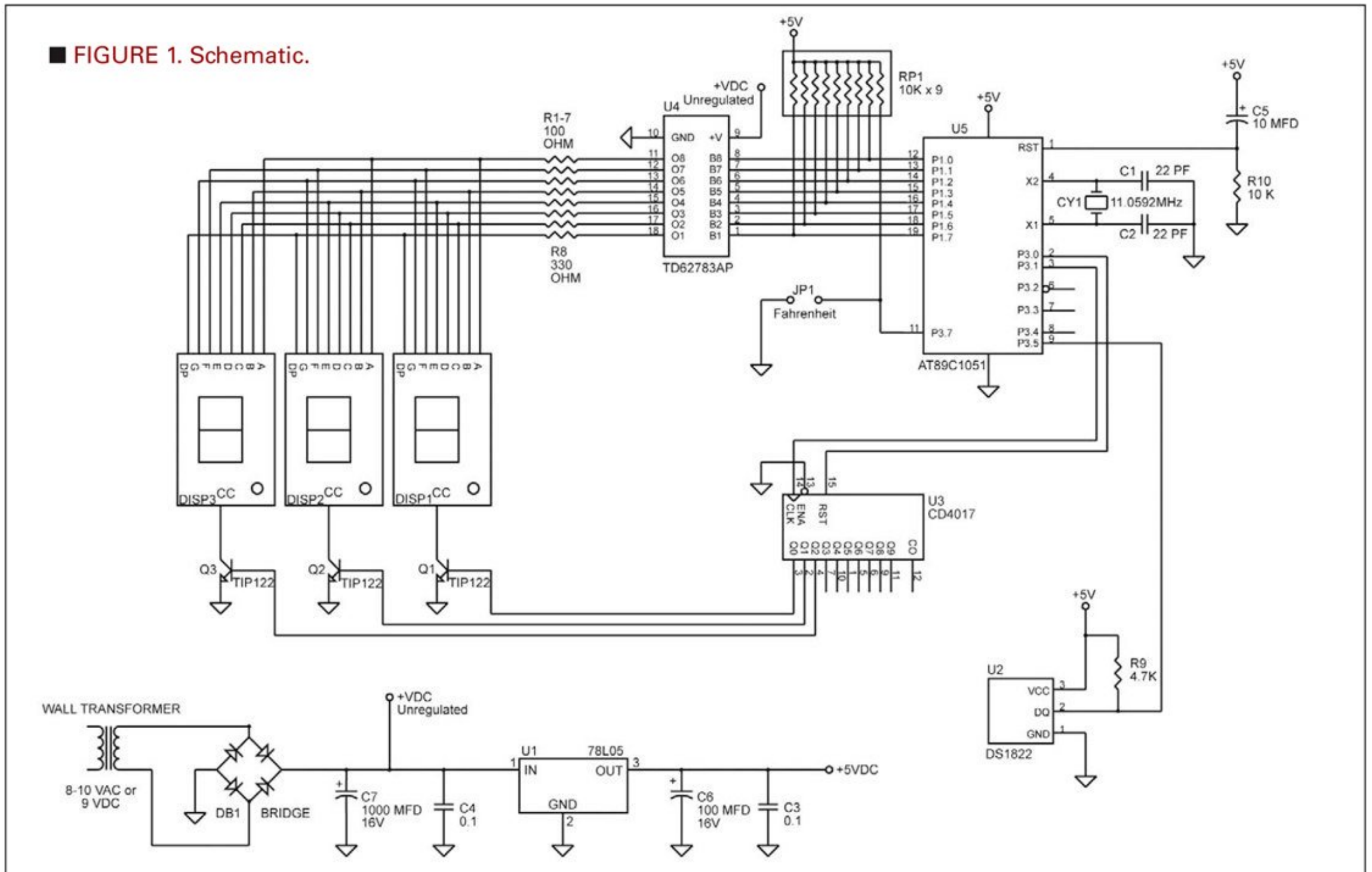
Circuit Description

At the heart of the jumbo LED thermometer is an ATMEL AT89C2051 microcontroller. It has been programmed to handle a variety of functions, including display multiplexing, temperature conversion, and seven-segment encoding. The AT89C2051 has 2K of Flash program memory, 128 bytes of RAM, 15 I/O lines, one 16-bit timer, an analog comparator, and three interrupt sources. It is fully compatible with the Intel MCS-51 architecture and instruction set.

Even though the microcontroller is handling most of the functions of the thermometer, some additional circuitry is required. Refer to the schematic shown in **Figure 1**. The circuit receives power from a 9-12V DC or AC wall-mount transformer. The full-wave bridge DB1 ignores the incoming voltage polarity if it is DC or else rectifies it to DC if it is AC. The voltage is filtered by capacitors C7 and C4, and then regulated to five volts DC by U1. Capacitors C6 and C3 provide additional filtering for the five volts.

Capacitor C5 and resistor R10 provide a RESET signal to U5 at power-on. The three LED displays (DISP1-3) do not require a regulated DC voltage, so they are driven by

■ FIGURE 1. Schematic.

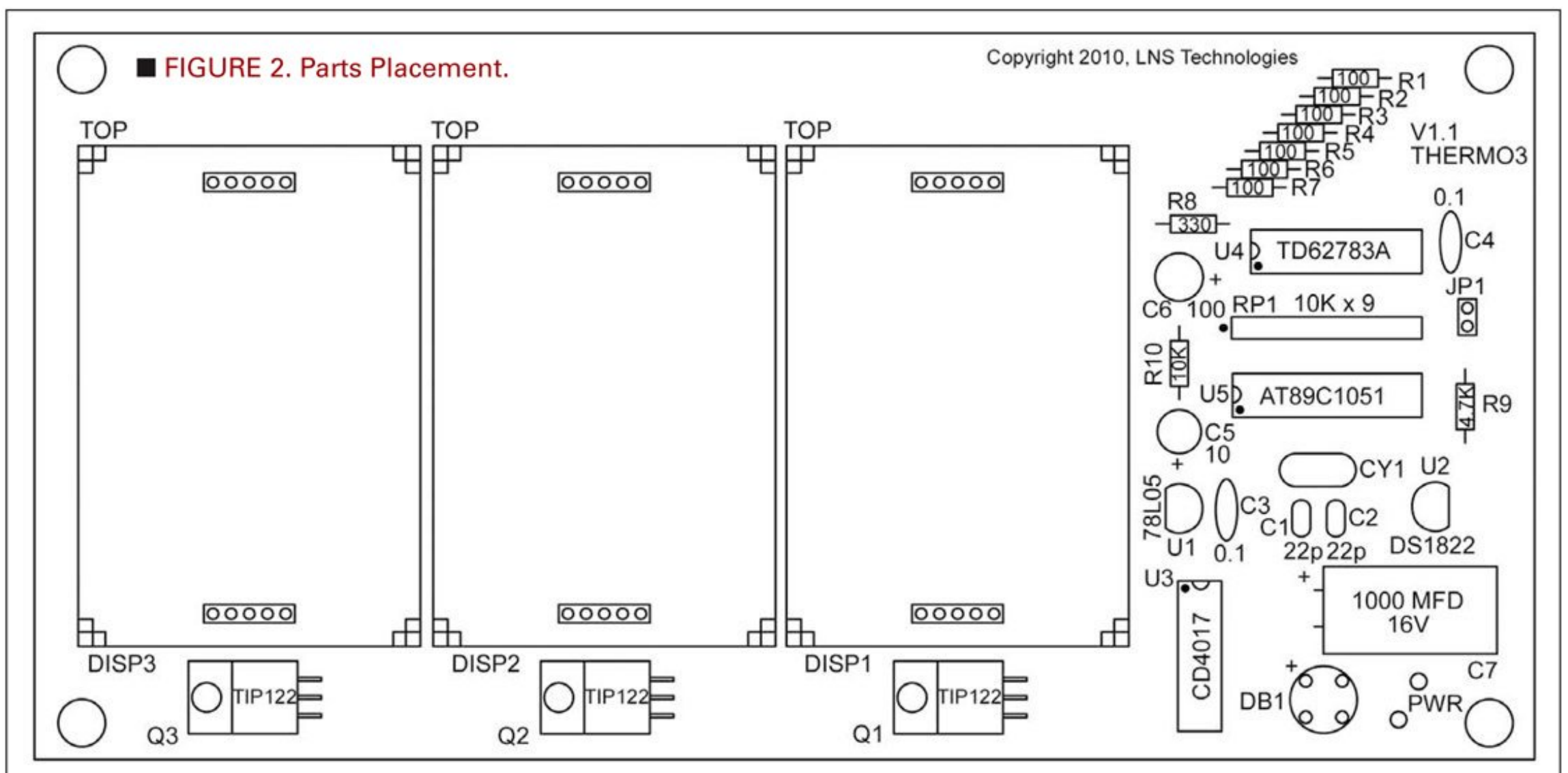


the unregulated voltage from DB1. Jumper JP1 allows the user to configure the thermometer to display either Centigrade or Fahrenheit temperatures.

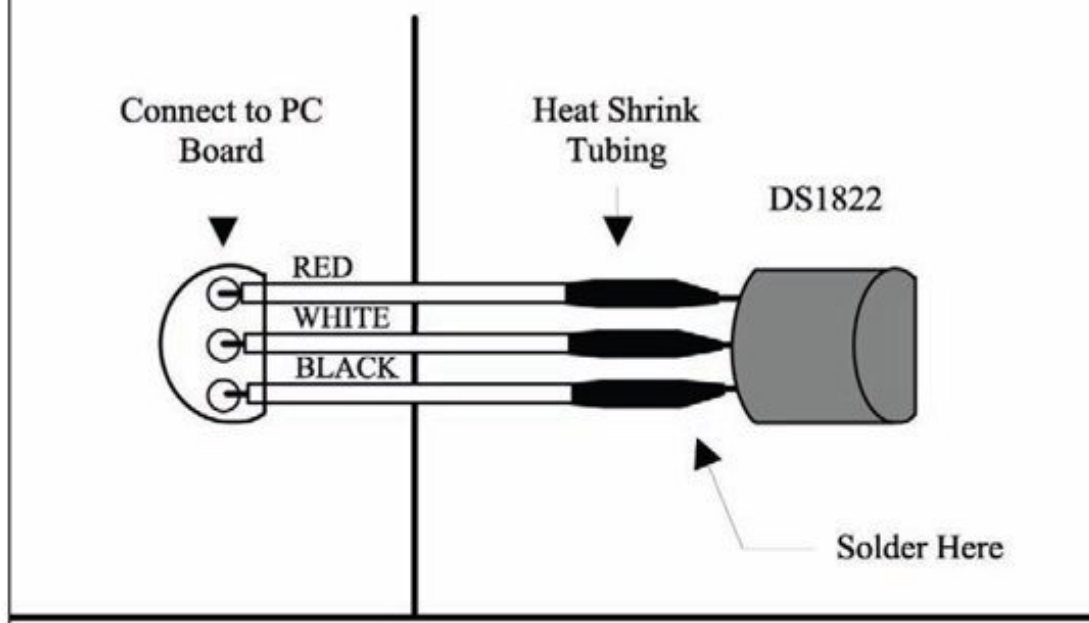
The jumbo thermometer uses three large seven-segment LED displays. In this circuit, the seven segments

of all three displays are bussed together. Each display digit can be selected by an output from the CD4017 decade counter U3. This configuration allows any digit to be addressed by the microprocessor using a technique called multiplexing.

■ FIGURE 2. Parts Placement.



DS1822 WIRE CONNECTIONS



■ FIGURE 3. Connections.

Multiplexing

Multiplexing involves lighting each of the three LED digits one at a time. Even though only one digit is on at any single moment, the scanning is done so quickly that all three digits appear to be lit simultaneously. The seven segments of each digit are controlled by seven data lines from the AT89C2051 microcontroller U5. During multiplexing, it is necessary to drive the LED's with more current than the pins of the AT89C1051 can provide, so the PNP darlington drivers in U4 are used to provide the additional LED source current capacity. U4 also does voltage level shifting, allowing the displays to be driven from the unregulated input voltage. The CMOS decade

Thanks to the amazing DS1822 digital sensor from Maxim Integrated Products, no temperature calibration is required for this thermometer. The DS1822 digital sensor provides 9- to 12-bit Centigrade temperature measurements. It has an operating temperature range of -55°C to $+125^{\circ}\text{C}$, and is accurate to $\pm 2.0^{\circ}\text{C}$ over the range of -10°C to $+85^{\circ}\text{C}$.

The DS1822 communicates over a 1-Wire™ serial data bus. The bus was originally designed by Dallas Semiconductor to provide low-speed data, signaling, and power over a single signal wire. Of course in real applications, the bus requires at least one more wire for a ground connection. Even though most 1-Wire devices can take their power directly from the same wire used for data communications (parasitic supply), projects can be more robust if an additional wire is used for powering the device.

So in this application, the DS1822 actually uses three wires. Perhaps naming it the 3-Wire bus would not have sounded as interesting.

1-Wire is currently a registered trademark of Maxim Integrated Products, Inc.

counter U3 provides a way to turn on each of the three digits in sequence. U3 cannot drive the digits directly, so six TIP122 NPN darlington transistors (Q1-3) are used for LED current sinking.

Two output lines go from the microcontroller to U3. One is used to reset the counter, so the data presented to the seven-segment outputs can be synchronized with the proper digit. The other is connected to the clock input of the CD4017 and is used to increment the counter. Each

PARTS LIST

Digi-Key Corp; www.digikey.com
Jameco Electronics; www.jameco.com

REF	DESCRIPTION
C1,C2	Capacitor, 22 pF, 50V Monolithic
C3,C4	Capacitor, 0.1 mfd, 50V Ceramic
C5	Capacitor, 10 mfd, 16V Electrolytic
C6	Capacitor, 100 mfd, 16V Electrolytic
C7	Capacitor, 1,000 mfd, 25V Electrolytic
DB1	Diode Bridge, 1.5A, 100V, W01
R1-7	Resistor, 100 ohm, 1/4W, 5%
R8	Resistor, 330 ohm, 1/4W, 5%
R9	Resistor, 4.7K ohm, 1/4W, 5%
R10	Resistor, 10K ohm, 1/4W, 5%
U1	IC, LM78L05, 5V Regulator, 100 mA
U2	IC, DS1822 one-Wire Temperature Sensor
U3	IC, CD4017 Decade Counter
U5	IC, AT89C2051 Programmed with software
U4	IC, TD62783AP, 8 CH Source Driver
Transistor,	NPN, TIP122
CY1	Crystal, 11.0592 MHz, HC49US
TXFR	Transformer, Wal, 12 VDC, 700 mA
DISP1-3	Display, LED seven-Seg CC, 2.3 in, LSD23255

SUPPLIER PART

A complete kit, a printed circuit board, or a pre-programmed microcontroller can be purchased from the *Nuts & Volts* Webstore (www.nutsvolts.com) or call our order desk at 800 783-4624.

Digi-Key Electronics (DS1822-ND)

Digi-Key Electronics (TD62783APG-ND)Q1-3

Jameco Electronics (325227)

Jameco Electronics (97201)

MISCELLANEOUS

Jumper post and shorting block; IC sockets; Hex spacers - 3/4 inch length; Acrylic plastic front panel; #4-40 screws; three-conductor wire.

time the counter is incremented, the next digit is enabled. The multiplexing works as follows: First, the microcontroller resets the decade counter to enable digit DISP1. Then, data is output to the seven-segment lines to turn on the appropriate LED segments in the first display. The LED segments in DISP1 are left on for only two milliseconds. Next, a clock pulse is generated to increment U3. As the counter increments, DISP1 is turned OFF and DISP2 is enabled. At the same time, the seven-segment data is changed to turn on the appropriate LED segments of the second display. The sequence continues for each of the three digits before the entire process is repeated. This gives the display a 1/3 duty cycle and a refresh rate of 166 times per second. At that speed, the human eye cannot perceive the multiplexing and the digits appear to be lit continuously.

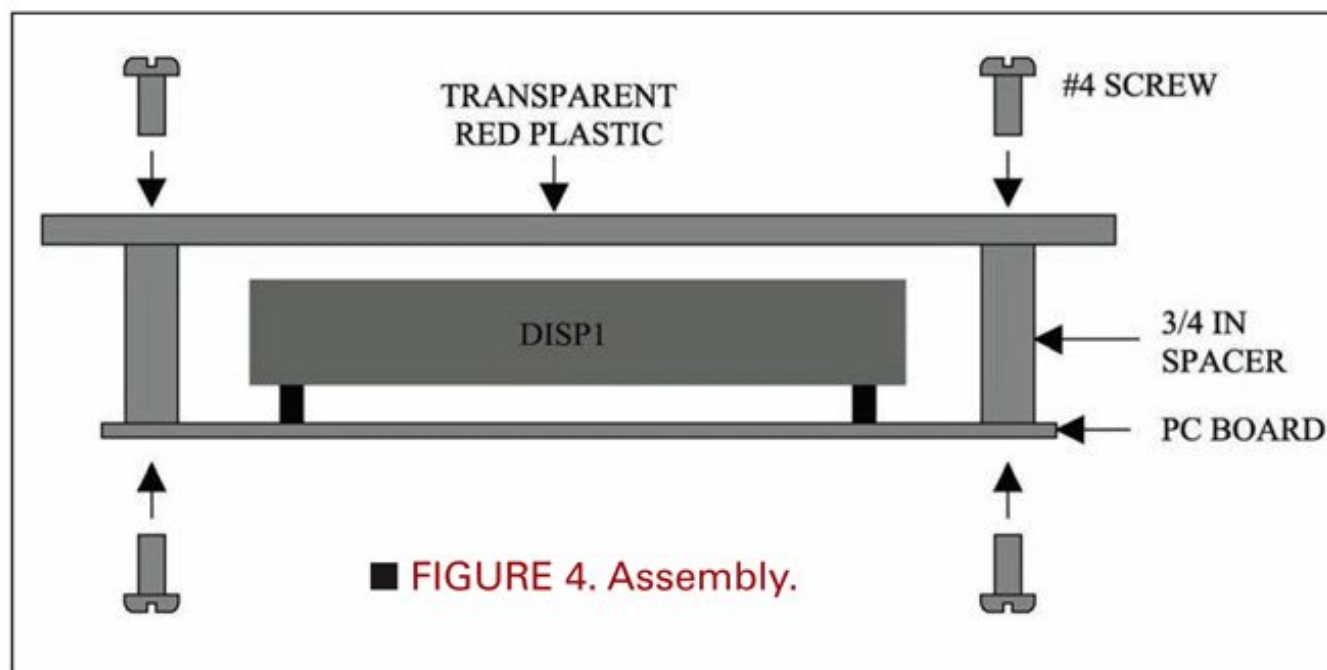
Construction Hints

The **Parts List** shows all of the individual components needed for this project. The HEX program file for the microcontroller and the PCB Gerber files are available for download on the *Nuts & Volts* website (www.nutsvolts.com). Alternatively, the pre-programmed microcontroller, printed circuit board, or an entire kit of parts is available for purchase (ordering details shown in the **Parts List**).

Figure 2 shows the component placement locations on the printed circuit board (PCB). Double-check the solder connections as you go along. Mount the resistors and crystal to the PCB first. Then, solder in the NPN transistors and the diode bridge, followed by the three IC sockets. Next, solder in the resistor pack RP1 and the mono/ceramic capacitors C1-C5.

Move on to the voltage regulator and the three seven-segment LED displays. Make sure the displays are oriented so the decimal points match what's shown in **Figure 2**. Next, mount the jumper post and the electrolytic capacitors. Note that capacitor C7 has to be mounted differently from capacitors C5 and C6 in order to clear the red front panel. C7 lies on its side against the PCB. Lastly, connect the power supply wires from the wall transformer and the DS1822 sensor.

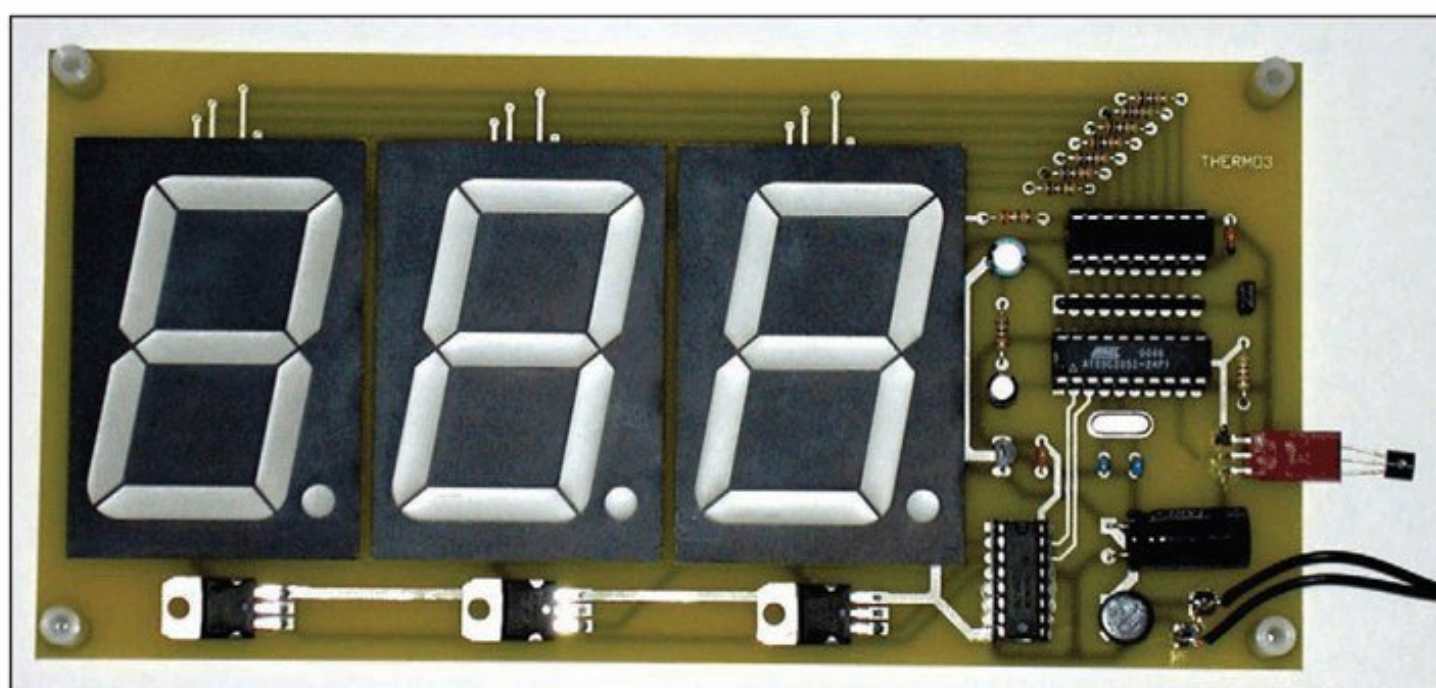
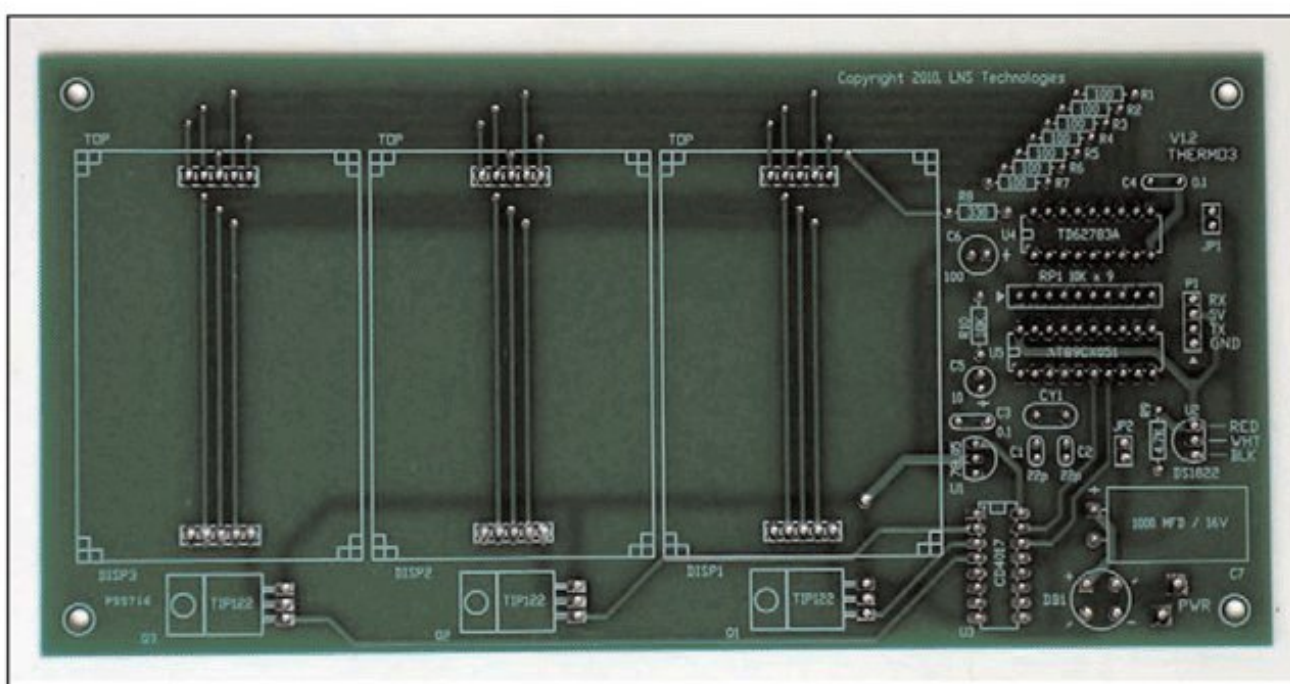
Use approximately 12 inches of three-conductor wire to remotely connect the DS1822 to the PCB as shown in **Figure 3**. Since the DS1822 sensor will be in water for aquarium use, seal U2 and the wire connections using waterproof epoxy or silicon. A transparent red acrylic front panel will give an attractive finished look



to your thermometer. **Figure 4** shows the final assembly details for mounting the plastic panel to the PCB using four standoffs and eight screws.

Operation

Operation of the jumbo LED thermometer should be straightforward. If jumper JP1 is shorted, the display will be in Fahrenheit. If JP1 is left open, the display will be in Centigrade. Plug the wall transformer power supply into an AC outlet and within two seconds, the display should show the digital temperature. If the display flashes "EEE" the DS1822 sensor was not detected. Re-check the wire connections to U2 if you encounter this situation. **NV**



Reading and Writing an EEPROM

Using the Arduino

My brother-in-law has five out-of-production CNC machines he uses in his business, three of which had stopped working. By process of elimination, he found the culprit to be a Xicor X88C64 EEPROM that translated user commands to servo controls. Unable to buy programmed replacement chips and finding commercial programmers to duplicate one of his remaining working EEPROM chips prohibitively expensive, he asked me if I could help find a solution. I had gotten an Arduino Duemilanove for Christmas and had experimented with it enough to think it might provide a solution to his problem.

My first task was to Google the X88C64 EEPROM to locate the datasheet for the part (see [Links](#)). I looked for any operation that required completion faster than would be possible for the Arduino. The only instance I found was that every write during a Page Write operation must be completed in less than 100 μ s. Since the Arduino runs at 16 MHz, it has a clock period of 62.5 ns ($\frac{1}{16 \times 10^6}$) which would allow plenty of instructions to meet the timing requirements.

In looking at the chip specification, I noted that I would need 13 digital pins for the address/data bus plus several control leads. This would be a problem for my existing Arduino, however, since it only supports 13 digital pins (and two of those are needed for serial I/O). Not wanting to add external

circuitry, I decided on an Arduino Mega which has 54 digital pins. (I'll use any excuse to get some new gear!)

Another interesting aspect of the X88C64 was that the eight data bits and the lower eight address bits shared the same pins using the Address Latch Enable (ALE) control to designate when the pins are addresses. Since the Mega pins can be easily changed from output to input, I didn't think this would be much of a problem.

Another issue I would need to address was that the X88C64 had 8K bytes of EEPROM. My original thought was to load the contents of a working EEPROM into an array, and then replace the chip with a blank EEPROM and write the array contents into the new chip. However, since the Mega only has 8K bytes of RAM that wouldn't

Signal	Register	Register Bit	Arduino Mega Pin
Address 12	C	4	33
Address 11	C	3	34
Address 10	C	2	35
Address 9	C	1	36
Address 8	C	0	37
Address/Data 7	A	7	29
Address/Data 6	A	6	28
Address/Data 5	A	5	27
Address/Data 4	A	4	26
Address/Data 3	A	3	25
Address/Data 2	A	2	24
Address/Data 1	A	1	23
Address/Data 0	A	0	22
ALE	L	0	49
RD	L	1	48
WR	L	2	47
CE Master	L	3	46
CE Slave	L	4	45
WC	L	5	44

Figure 1.

Register bits and Mega pins used for X88C64 address, data, and control signals.

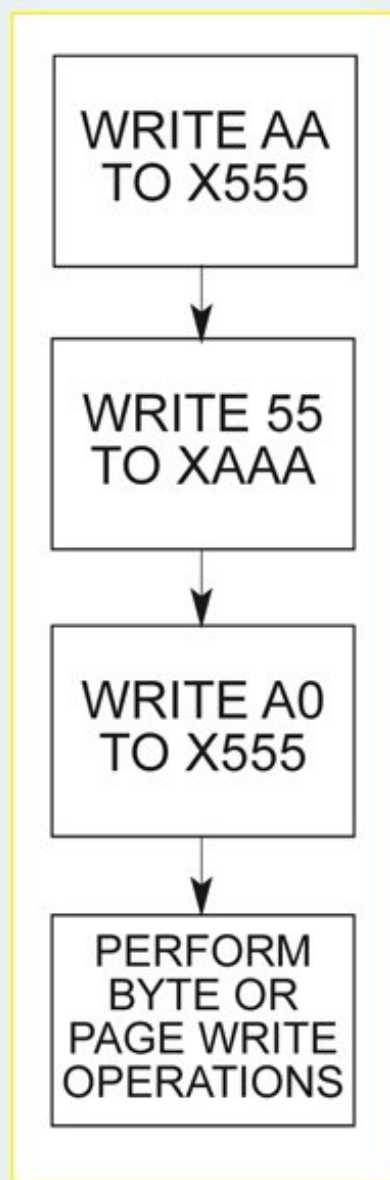


Figure 3.

Write sequence required by the X88C64.

EEPROMs remaining, I didn't want to take a chance of accidentally overwriting a working chip. I settled on a design that had two ZIF sockets: one for the working EEPROM (Master) and one for the blank EEPROM (Slave). I could then read and write on a byte-by-byte basis and not require RAM storage in the Mega. This also would allow me to scale up to any size EEPROM. The downside was more involved wiring on the breadboard.

Direct Port I/O

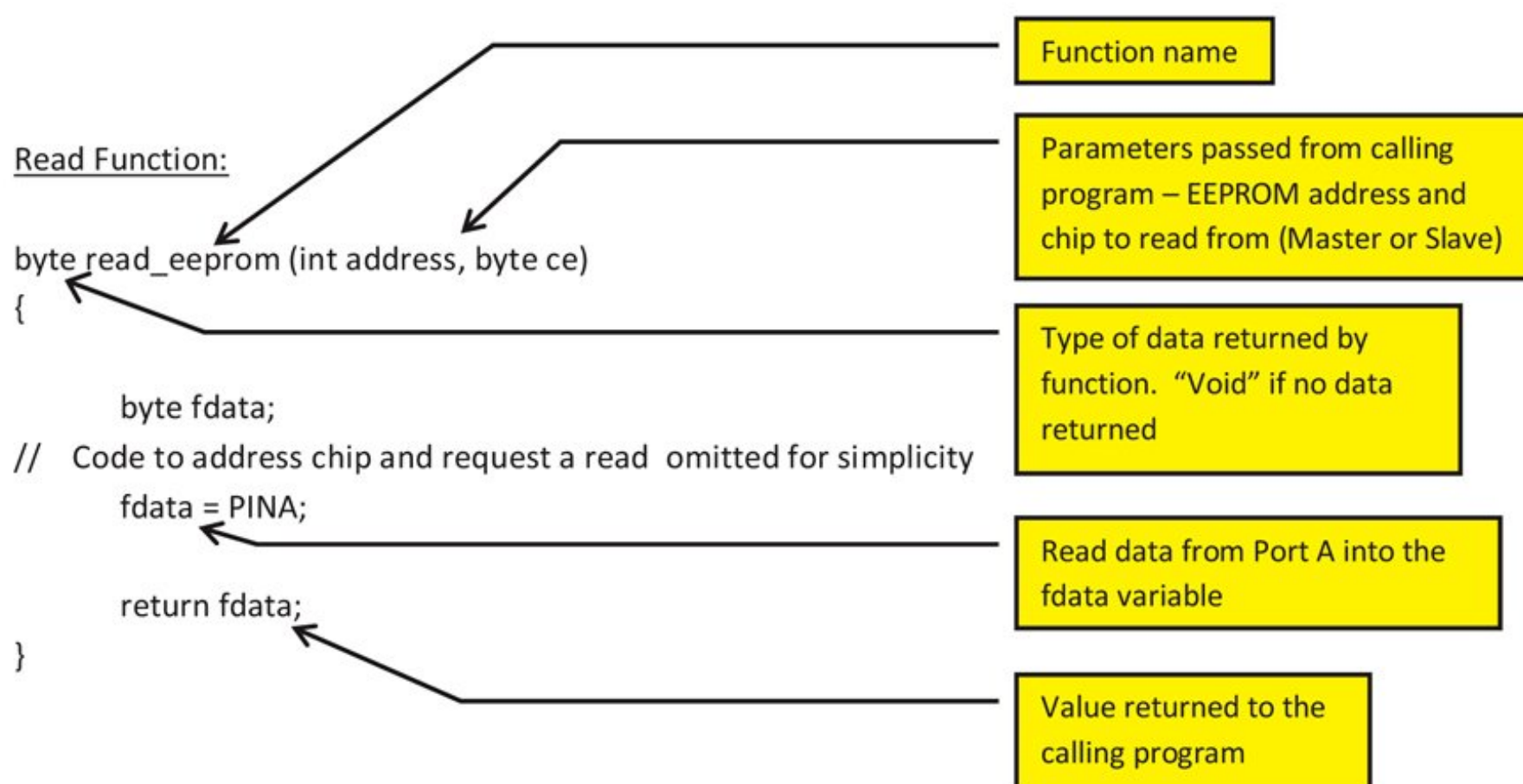
The digitalWrite Arduino command is actually setting

Code from the main program calling the function:

```
edata = read_eeprom(eaddr, ce_master);
```

Figure 2.

Read EEPROM function definition.

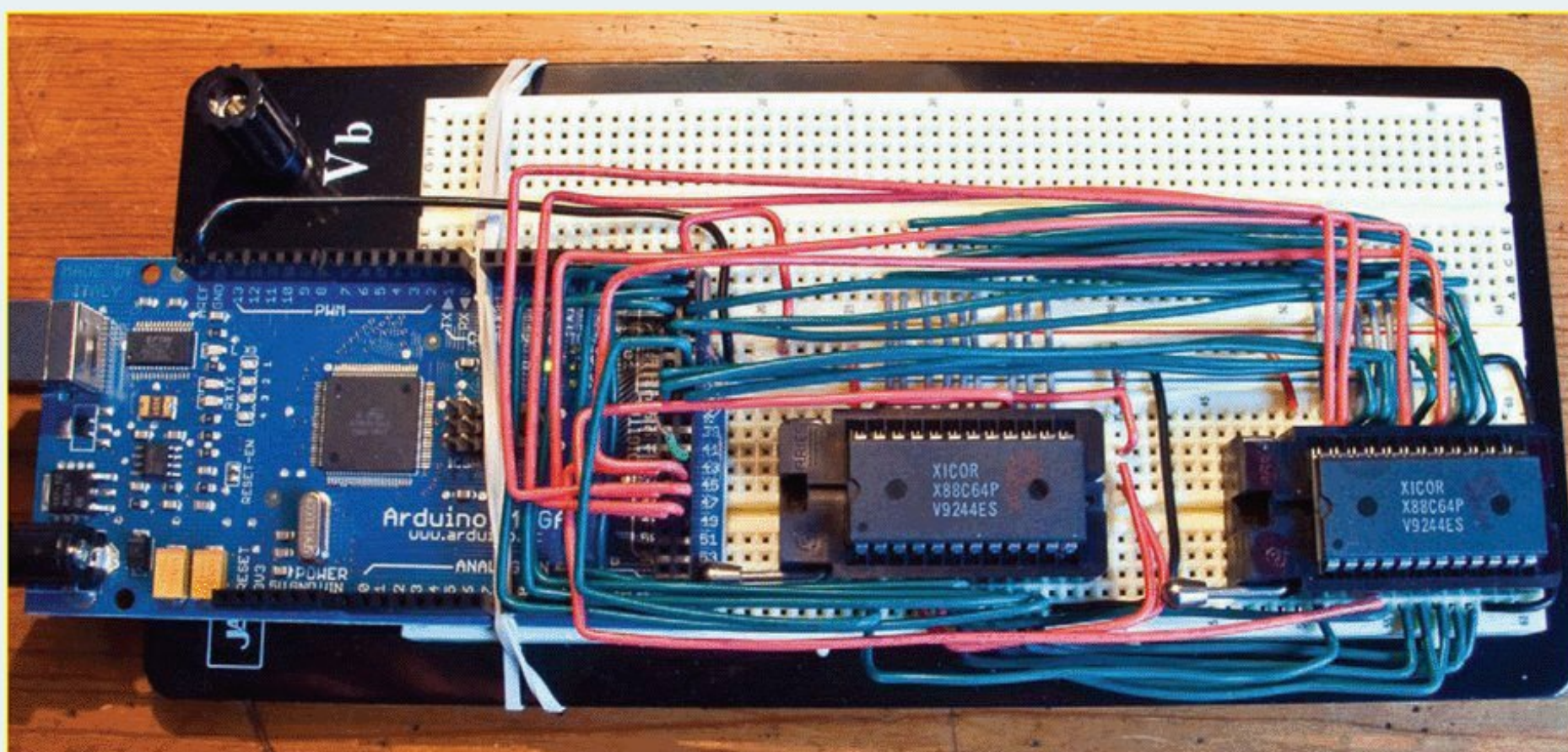


work. I then considered reading 4K into an array and swapping the chips twice to complete the copy. Since we only had two good

one bit in an eight-bit register. The ATmega1280 CPU used in the Mega has 11 registers designated PORTA through PORTL (PORTI is not defined) of which 54 digital bits are brought out to connectors on the Mega board. [See the ATmega 1280 datasheet section 13 (in **Links**) for more details.] For my programmer, I need to control all 13 address bits and read or write eight data bits, so setting bits one at a time would be quite inefficient. Also, it takes much less time to control the ports directly, even though (in my case) performance was not an issue. Each port pin actually consists of three register bits – DDRxn, PORTxn, and PINxn – where x designates the port (A through L) and n specifies the bit (0 through 7). The DDRxn bit specifies the direction of the pin. If DDRxn is set to a logic one, the pin is an output. If DDRxn is set to a logic zero, the pin is an input. PORTxn is used to set output data and

Figure 4.

Final breadboard layout. Master EEPROM is on the left (read only) and the blank Slave EEPROM (writeable) is on the right.



WR Controlled Write Timing Diagram

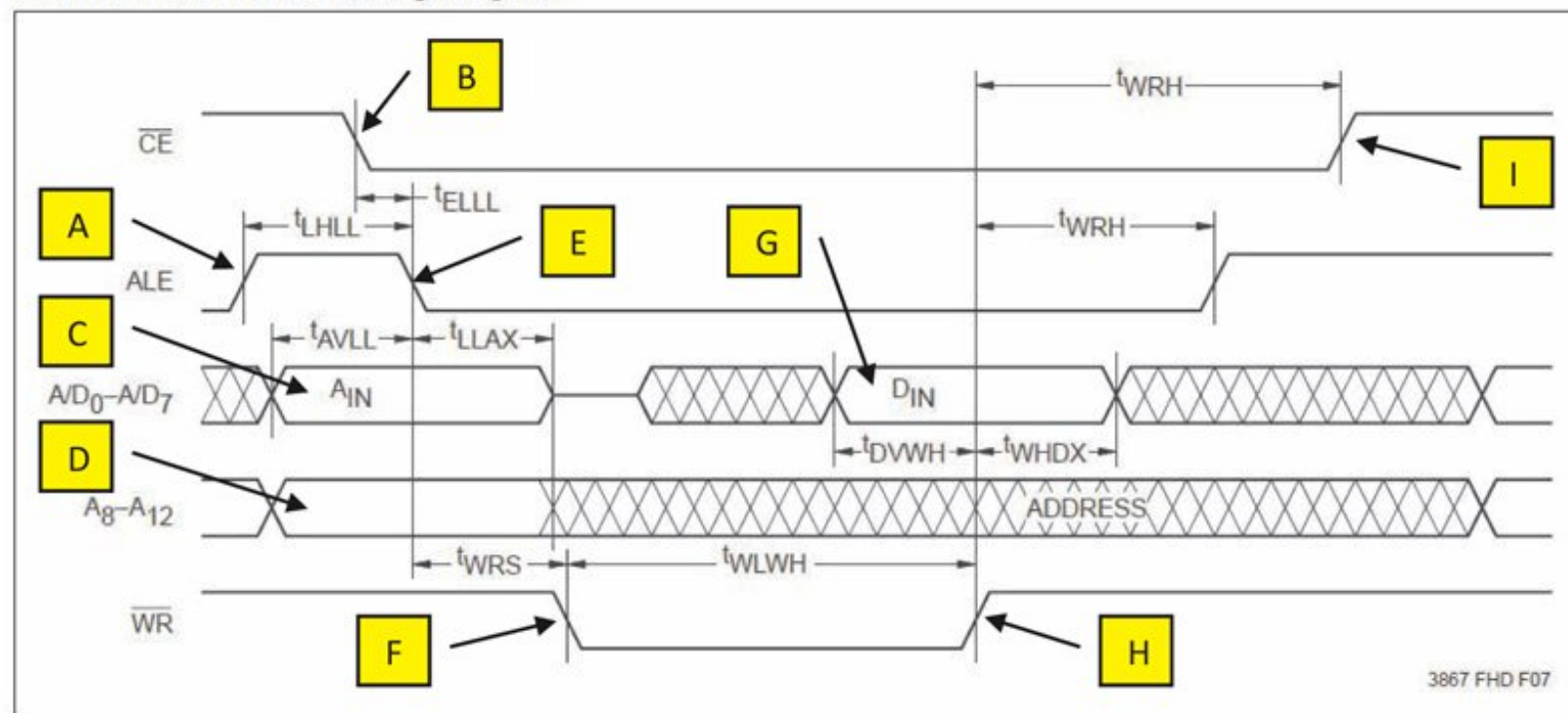


Figure 5.

Using the Arduino to control X88C64 EEPROM write timing signals.

```
PORTL = PORTL & ~(1 << rd); //RD LOW
```

I'll explain this starting from the right side of the statement.

1. `rd` is a constant with a value of one, indicating the position of the `RD` bit in the register.

2. `1 << rd` means to shift a 1 bit in position 0, one bit to the left = 0 0 0 0 0 0 1 0.

3. `~` means a bitwise NOT operation which reverses the state of each bit = 1 1 1 1 1 1 0 1.

4. `PORTL` at this point in the program is 1 1 1 0 1 1 0 (CE Master, ALE = 0; other bits = 1. See **Figure 1** for port bit definitions.)

This results in:

a. Value from step 3: 1 1 1 1 1 1 0 1

b. Initial `PORTL`: 1 1 1 0 1 1 0 1

c. `&` (bitwise AND): 1 1 1 0 1 1 0 0 (final value of `PORTL` – note only bit 1 changed.)

For more information on bitwise logical operations, see the **Links sidebar**.

To determine which Mega pin the register bit connects to, refer to the Mega **schematic** (see **Links**). For example, my

read pin is bit 1, register L. On the ATmega1280 chip (on the **schematic**), this is designated as PL1 and is chip pin 36. This signal connects to header JP2 which is pin 48 on the board. See **Figure 1** for the registers and pins used for the EEPROM programmer.

Functions Simplify the Program

Any time you find blocks of code that are repeated in

```
void raw_write(int raddress, byte rdata)
```

```
{
    DDRA = 0xff; //ad0 - 7 output for addressing

    A → PORTL = PORTL | (1 << ale); //ALE HIGH
    B → PORTL = PORTL & ~(1 << ce_slave); //Enable chip - CE LOW
    C → PORTA = raddress; //address bits 0 - 7
    D → PORTC = raddress >> 8; //address bits 8 - 12
    __asm__("nop\n\t"); //meet tAVLL address setup time
    E → PORTL = PORTL & ~(1 << ale); //ALE LOW
    __asm__("nop\n\t"); //meet tLLAX address hold time
    F → PORTL = PORTL & ~(1 << wr); //WR LOW
    G → PORTA = rdata; //data output on bits 0 - 7
    __asm__("nop\n\t"); //meet tDVWH data setup time
    H → PORTL = PORTL | (1 << wr); //WR HIGH
    __asm__("nop\n\t"); //meet tWHDX data hold time
    I → PORTL = PORTL | (1 << ce_slave); //Disable CE
}
```

`PINxn` is used to read data. For example, I used bit 1 of the L register for the `RD` (read – active low) control signal. To send the read signal to the EEPROM, `DDRL` bit 1 must be set to one and then `PORTL` bit 1 set to zero. Once the read is complete, bit 1 is set to one. The `DDR`, `PORT`, and `PIN` register values are already defined when you write an Arduino sketch. Just be aware that the values must be entered in upper case. Another important consideration when setting control bits such as `RD` is that only the specified bit should change while all the other bits should keep their values. For example, if you examine my program you will see this code to activate the read signal:

your program, you might have a good candidate for using a function. **Figure 2** illustrates the function concept using the read EEPROM function. (The timing and port register controls have been removed to focus on the function parameters. Complete details of the function timing are shown in **Figure 5**.)

The end result of calling this function is that the `edata` variable contains the data at address `eaddr` in the Master EEPROM. In my `write_eeprom` function, no data is returned so the first word in the function statement is “void.”

Design

My first step was to build a quick prototype to prove the concept that I could actually read and write the EEPROM. I used a breadboard, a ZIF socket, and some pre-cut jumper wires to connect to the Arduino Mega. My first program just turned on each of the address, data, and control bits in turn, so I could verify the wiring using my logic analyzer. Without a logic analyzer, it would be extremely difficult to troubleshoot problems with a digital circuit like this. I use a Rigol DS1052D but there are many less expensive alternatives including an open source hardware/software logic analyzer that is around \$45. (See **Links**.)

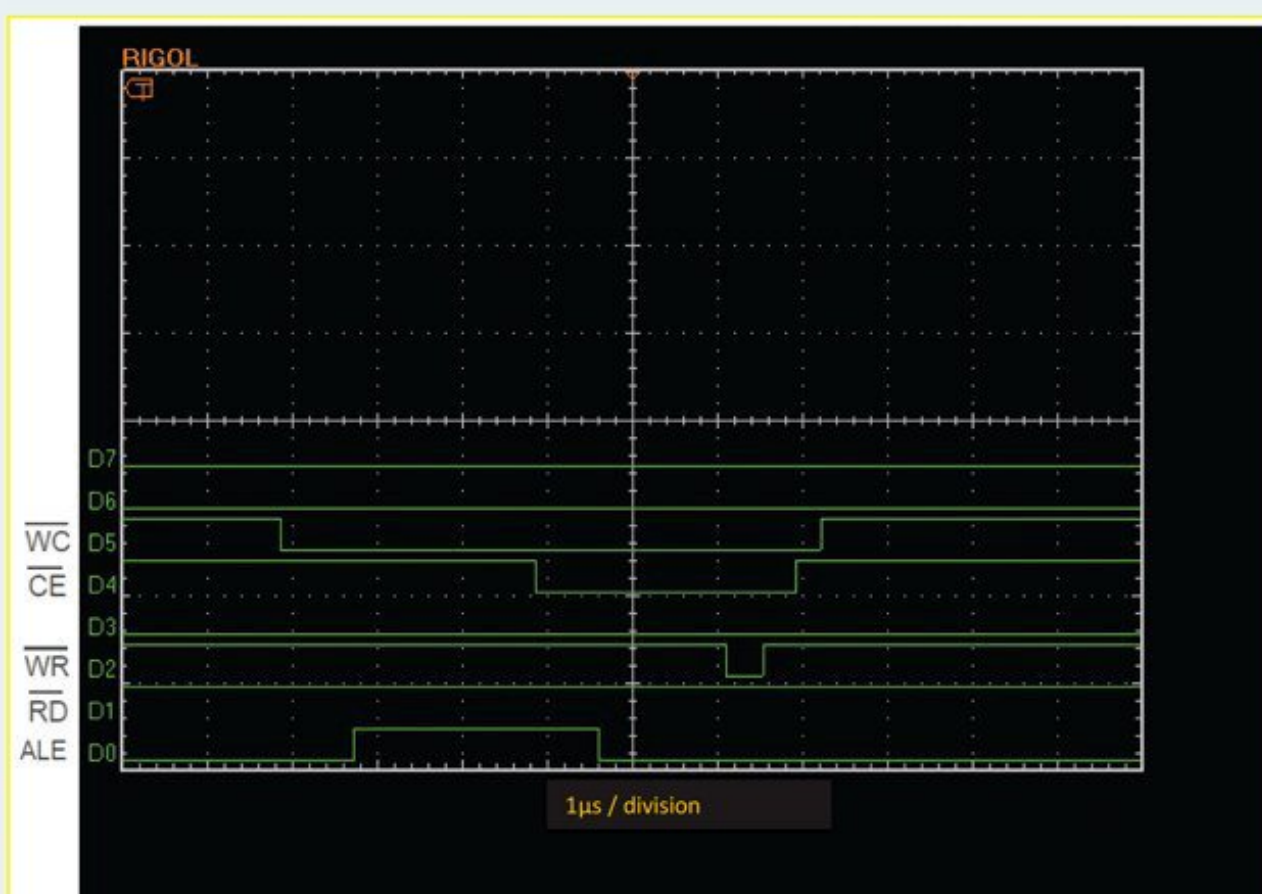
By the time I had completed the wiring the blank EEPROMs had arrived and I was ready for my first big test. I wrote a program to read all 8K bytes and display them on my PC. After tweaking a few programming errors, I had my first big success and a bit of a surprise. Instead of being blank, the new EEPROMs started at address 0 with 0xAA (hex) and then alternated 0x00 0xFF for 32 bytes, then changed to 0xFF 0x00 for 32 bytes, and repeated this for the remaining data.

Now I was ready for the ultimate test of writing data to the chip. However, the write operation was more complicated than the read because the chip used Software Data Protection (SDP) to protect against inadvertent writes as shown in **Figure 3**.

I wrote a program to write one byte of 0xBB at address 5 and read it back, but the output showed the write had failed. I checked the timing signals with the ones on the datasheet and everything looked correct. After much pointless troubleshooting, I decided to put the circuit away and reread the EEPROM datasheet from cover to cover. I discovered that there is one important control signal that is not included in the timing diagrams: Write Control — which I had failed to connect to the chip. This signal must be low for all write operations so I just connected it to ground and finally the write routine worked. Next, I modified the write routine to write a fixed pattern

Figure 6.

Logic analyzer trace when troubleshooting the failure to write the EEPROM. Can you spot the problem?



EEPROM Burner Program

void loop ()

The user is prompted to enter “r” for read or “w” for write. The read routine was used primarily for debugging purposes, and reads the entire EEPROM and computes a checksum by taking a bitwise XOR of each byte. The write routine first does a byte-by-byte copy from the Master to the Slave EEPROM. Next, each byte in the Slave is read and compared to the Master, and any errors are displayed using serial I/O. A checksum of the Slave is also displayed.

byte read_eeprom(int address, byte ce)

Generates the required timing signals to return one byte (`fdata`) at the specified address for either the Master or Slave EEPROMs. The parameter `ce` is the bit in the L register that provides the Chip Enable signal.

void write_eeprom(int address, byte data)

Writes one byte of data to the address specified in the Slave EEPROM. Note this function actually generates four write commands (calls to the `raw_write` function). The first three don’t actually change any value in the EEPROM but are used to prevent inadvertent writes to the chip. Only the fourth write command actually stores data in the EEPROM.

A delay is generated at the end of the function to make sure the t_{WC} maximum write timing is met.

void raw_write(int raddress, byte rdata)

Generates the write timing signals and data to the EEPROM.

Figure 5 shows the write timing diagram from the X88C64 datasheet and the corresponding write function showing how each signal is generated by the program. Note that the timing diagram is from the perspective of the EEPROM, while the function reflects signals from the Mega. (Output data from the function is input data to the EEPROM). The “nop\n\t” instructions are assembly code that represents a clock cycle delay or no operation (no-op). These were inserted to guarantee the setup and hold times required by the X88C64.

void disable_bpr()

The X88C64 has a feature called Block Protect Write where you can write protect individual 1K blocks of the EEPROM. This function makes sure this feature is disabled.

to the entire 8K bytes so I would have something to use to test my final copy program (initial value of 0xFF and decrement by one for every subsequent write).

Feeling satisfied that my design concept was sound, I wired up my final version connecting the Mega to the two

ZIF sockets. Not wanting to take any chances of damaging a working EEPROM, the Master socket had both the Write Control and Write signals tied high. My final design is shown in **Figure 4** with the address and data signal bus in green and the control signals in red.

Troubleshooting

Troubleshooting my final design mirrored the problems I had on my prototype — reads worked right away but I couldn't get the writes to work. Of course, one of the first things I examined was the Write Control that had been the cause of my prototype problems. In my final design, I had decided to control the signal from the Mega and make it active at the start of my `raw_write` function, then turn it off at the end as shown in **Figure 6**.

After going down many deadends, I reverted back to reading the EEPROM spec cover to cover again which finally revealed my error. The X88C64 specification states that "If the Write Control input is driven HIGH (before t_{BLC} Max), after Write goes HIGH, the write cycle will be aborted. The t_{BLC} max is 100 μ s and if you look, my write timing Write Control was going HIGH less than 1 μ s after Write went HIGH, causing every write to be aborted. In retrospect, I would have saved a lot of debugging time by just grounding Write Control. To correct the problem, I moved the Write Control to the main program and left it active for the entire time the chip was being written.

Success

My brother-in-law brought me a working EEPROM and I was able to duplicate it and get all his CNC machines working again. I also got an excuse to buy some new gear, and learn a lot about Arduino programming and troubleshooting along the way. Since this was a one-time project, there were several areas of possible improvement that I didn't pursue. For example, I made no attempt to optimize timing. (Read time was under one second, and write and compare was about one minute.) The chip specifies a worst case time between write cycles (t_{WC}) of 5 ms which is what I used in my program. However, by monitoring data bit 6 after the write the EEPROM indicates when the internal write has actually completed, which would typically be less than 5 ms.

While I'm probably the only person interested in programming an X88C64, this project illustrates how capable and cost-effective the Arduino platform is in providing an interface to control digital devices. The main consideration is to determine if the ATmega processor it uses is fast enough to generate the controls and process the data. There are many other special-purpose digital capabilities built in, such as I²C and USARTs — not to mention considerable power to process analog signals. All perhaps good topics for another article! **NV**

What is an EEPROM?

Did you ever wonder how a computer knows what to do when you first turn on the power? Whether the computer is in your PC, your car, the microwave oven, or a mainframe they all need some type of permanent program that is present even when the power is off. To put EEPROMs in perspective, it helps to know a bit of history about non-volatile memory (in roughly chronological order).

ROM - Read Only Memory

The information in ROM is permanently generated during the manufacturing process and can't be changed.

PROM - Programmable Read Only Memory

Also known as Field Programmable ROM (FPROM) or One Time Programmable Non-Volatile Memory (OTP NVM). These circuits can be programmed (burned) in the field by special-purpose programming machines. They can only be programmed once.

EPROM - Erasable Programmable Read Only Memory

Similar to a PROM except that it can be erased by a strong ultraviolet light. It's easy to recognize because the chip has a transparent quartz window on top of the package.

EEPROM - Electrically Erasable Programmable Read Only Memory

Permanent memory that can be changed under program control on a byte-by-byte basis. In the case of the EEPROM used in my project, the manufacturer does not publish information about the function of the chip. However, judging by its location in the circuit it is used to translate the manufacturing program in the PC into servo commands for a computer controlled milling machine.

Flash

Flash can also be changed under program control, and can be manufactured in higher densities and speed than EEPROM. However, the write operation can only occur on large blocks of data at a time.

If you examine the specification for the ATmega 1280 used in the Arduino Mega, you will see that it has both 128 KB Flash and 4 kB of EEPROM. The Flash is typically used for programs such as the power-up boot loader while the EEPROM can be used for storing program parameters and data that need to be permanently saved.

Xicor X88C64 Datasheet
www.datasheetcatalog.org/data-sheet/Xicor/mXyyzxsu.pdf

Atmega 1280 Datasheet
www.atmel.com/dyn/resources/prod_documents/doc2549.pdf

Arduino Bitwise Operations
www.arduino.cc/en/Reference/BitwiseAnd

Arduino Mega Schematic
<http://arduino.cc/en/uploads/Main/arduino-mega-schematic.pdf>

Atmega 1280 Port Register to Arduino Mega Connector References
http://t3.via.t42.org/u/Arduino_Mega_QuietschReferenz_v0_23.pdf

<http://spreadsheets.google.com/>

pub?key=rtHw_R6eVL140KS9_G8GpkA&gid=0

http://farm4.static.flickr.com/3321/3495394293_0d2c81798c_b.jpg

<http://spreadsheets.google.com/ccc?key=roX9D5pGrS4muSBjysz1QQ>

Open source logic analyzer

<http://dangerousprototypes.com/2010/02/25/prototype-open-logic-sniffer-logic-analyzer-2/>

www.seeedstudio.com/depot/preorder-open-workbench-logic-sniffer-p-612.html?cPath=75

Hex notation
<http://en.wikipedia.org/wiki/Hexadecimal>

Links

Experiments with Alternative Energy

Part 10 - Fuel Cell Basics

By John Gavlik, WA6ZOK

An exciting component in the field of alternative energy is the fuel cell. If powered by hydrogen, its fuel source can be extracted directly from water by electrolyzing (splitting) it into hydrogen and oxygen. Besides heat, the only byproduct a hydrogen fuel cell produces is water; when the two gasses are recombined internally, electricity is generated. Thus, the hydrogen fuel cell can be pollution-free and usually has more energy output as compared with a battery of the same size and weight. As such, fuel cells are beginning to draw the attention of many commercial applications including auxiliary power generators, powering your electric car, and replacing your cell phone battery to mention a few. Large stationary fuel cells already power homes and commercial buildings, and more are being added daily to supplement grid power (see the **Sidebar on Types of Fuel Cells**).

With all these advantages, why aren't fuel cells more popular and widespread? There are two main reasons: one is high cost and the other is the lack of a safe, pollution-free fuel source in a form that is suitable for direct energy conversion to electricity. For example, a hydrogen fuel cell uses platinum for its MEA (Membrane Electrode Assembly) — see the **Sidebar on MEA** which is one of the most expensive and rare metals on earth. Plus, hydrogen is not naturally available in free form since it is chemically bonded to other elements like oxygen in water and in natural gas where a great deal of energy is required to extract it in pure form. There are other fuel cell types like methanol, alkaline, and solid oxide, and each have their own advantages

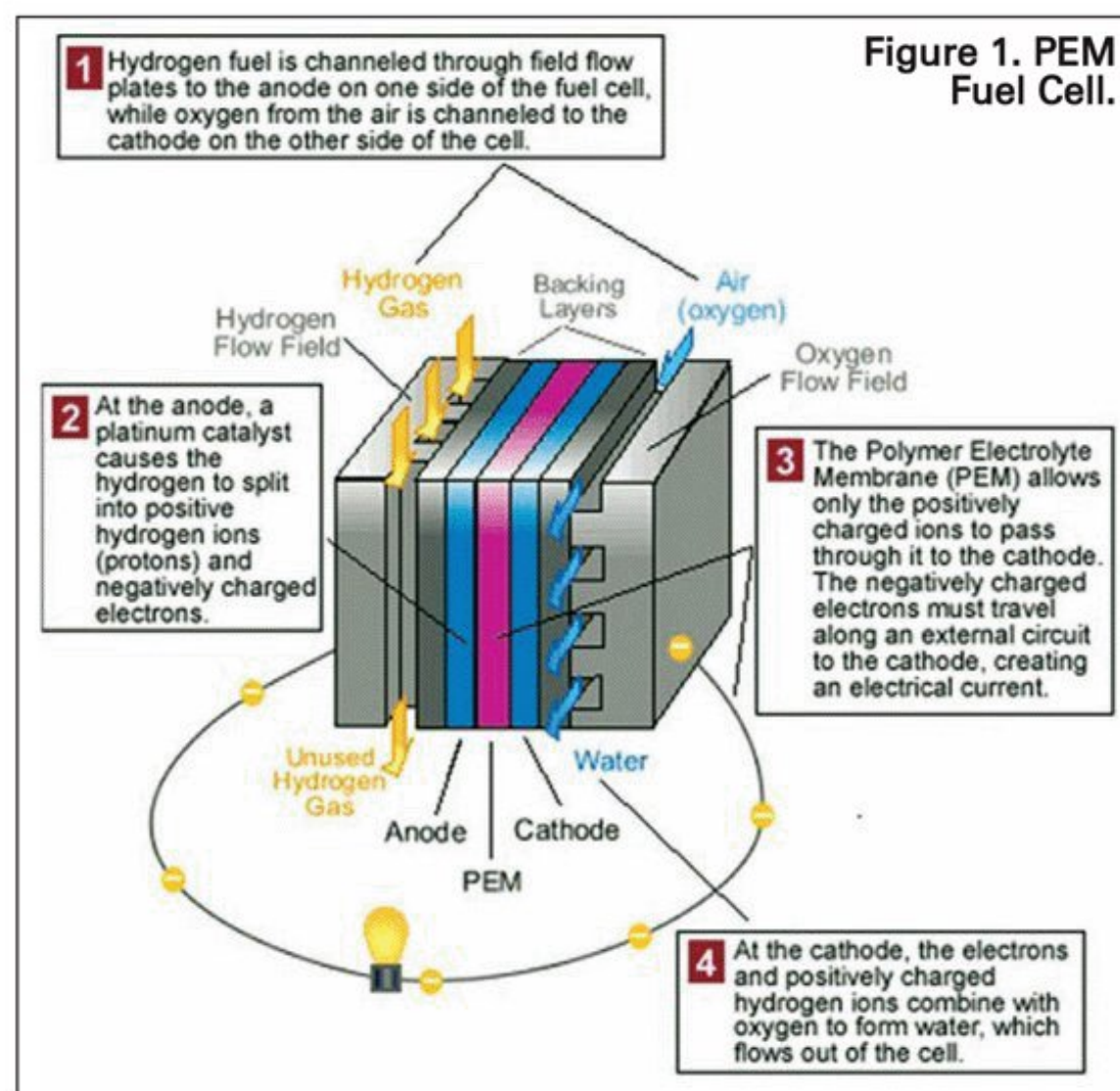
and drawbacks including again cost, as well as toxicity and safety issues. Things are beginning to change, however, in favor of fuel cell technologies to make them more affordable with greater fuel availability along with safer operating and storage conditions. With that in mind, let me introduce you to this technology by doing some interesting experiments with one of them.

The PEM "Reversible" Fuel Cell

There are many types of fuel cells out there to choose from but the one that can demonstrate most of a fuel cell's characteristics, as well as be affordable, easy to use, and safe is the PEM reversible fuel

cell. PEM can mean Proton Exchange Membrane or Polymer Electrolyte Membrane. Take your pick — both refer to the part that separates the hydrogen protons and electrons to produce electricity (**Figure 1**). The reversible part means that it serves as both an electrolyzer for water to create hydrogen and oxygen, as well as a fuel cell. You get the best of both worlds with this device as it mimics a rechargeable battery. The main difference is that the electrolyte is external and does not get used up in the process of generating [DC] electricity. It can continue to generate electricity as long as hydrogen and oxygen are available.

A reversible PEM fuel cell operates in two distinct modes:



Types of Fuel Cells

PEMFC - Polymer exchange membrane fuel cell

The Department of Energy (DOE) is focusing on the PEMFC as the most likely candidate for transportation applications. The PEMFC has a high power density and a relatively low operating temperature (ranging from 60 to 80 degrees Celsius, or 140 to 176 degrees Fahrenheit). The low operating temperature means that it doesn't take very long for the fuel cell to warm up and begin generating electricity.

SOFC - Solid oxide fuel cell

These fuel cells are best suited for large-scale stationary power generators that could provide electricity for factories or towns. This type of fuel cell operates at very high temperatures (between 700 and 1,000 degrees Celsius) which makes reliability a problem because parts of the fuel cell can break down after cycling on and off repeatedly. However, solid oxide fuel cells are very stable when in continuous use. In fact, the SOFC has demonstrated the longest operating life of any fuel cell under certain operating conditions. The high temperature also has an advantage in that the steam produced by the fuel cell can be channeled into turbines to generate more electricity. This process is called co-generation of heat and power (CHP) and it improves the overall efficiency of the system. The Bloom Box is one type of SOFC.

AFC - Alkaline fuel cell

This is one of the oldest designs for fuel cells; the

United States space program has used them since the 1960s. The AFC is very susceptible to contamination, thus it requires pure hydrogen and oxygen. It is also very expensive, so this type of fuel cell is unlikely to be commercialized anytime soon but some companies are still trying.

MCFC - Molten-carbonate fuel cell

Like the SOFC, these fuel cells are also best suited for large stationary power generators. They operate at 600 degrees Celsius, so they can generate steam that can be used to generate more power. They have a lower operating temperature than solid oxide fuel cells which means they don't need such exotic materials. This makes the design a little less expensive.

PACF - Phosphoric-acid fuel cell

The phosphoric-acid fuel cell has potential for use in small stationary power-generation systems. It operates at a higher temperature than polymer exchange membrane fuel cells, so it has a longer warm-up time. This makes it unsuitable for use in most vehicles.

DMFC - Direct-methanol fuel cell

Methanol fuel cells are comparable to a PEMFC in regards to operating temperature, but are not as efficient. Also, the DMFC requires a relatively large amount of platinum to act as a catalyst which makes these fuel cells very expensive.

Source - www1.eere.energy.gov/hydrogenandfuelcells/fuelcells/fc_types.html

Electrolysis Mode and Fuel Cell Mode. There are also two chemical processes involved: oxidation and reduction.

In the Electrolysis Mode (**Figure 2**), water is introduced to both sides of the MEA where it is split into hydrogen at the cathode (negative) and oxygen at the anode (positive) by a small voltage level less than 1.5 volts DC called the water

decomposition voltage that you'll learn more about later. Hydrogen collects at the cathode and oxygen is created at the anode. Electrolysis of pure water requires excess energy in the form of overpotential to overcome various activation barriers. Without the excess energy, the electrolysis of pure water occurs very slowly if at all. This is, in part, due to the limited self-ionization of water.

Pure water has an electrical conductivity about one millionth that of seawater. Nevertheless, electrolysis can be accomplished. If you're a chemistry buff, here are the chemical reactions:

Electrolysis Mode Reactions

- Anode reaction: $2\text{H}_2\text{O} \rightarrow 4\text{H}^+ + 4\text{e}^- + \text{O}_2$
- Cathode reaction: $4\text{H}^+ + 4\text{e}^- \rightarrow 2\text{H}_2$

MEA - Membrane Electrode Assembly

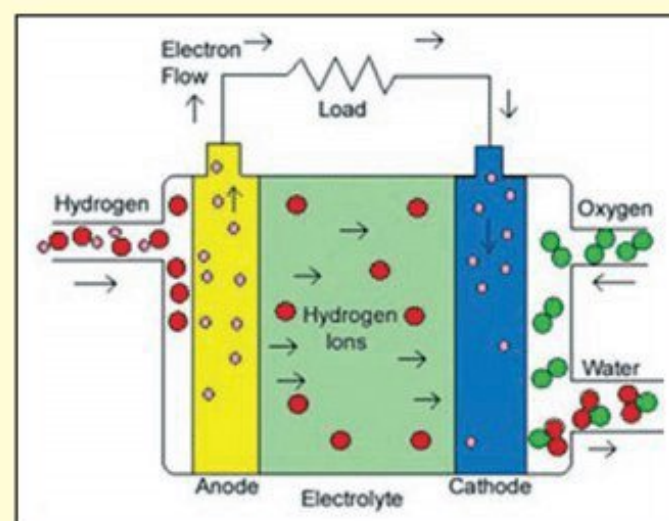
The membrane electrode assembly — or MEA — is the heart of a hydrogen fuel cell. It consists of the ion-exchange membrane, platinum anode and cathode electrodes, and gas diffusion and catalyst layers. Here's basically how it works with hydrogen and oxygen to create electricity:

The Anode — the negative side of the fuel cell — conducts the electrons that are freed from the hydrogen molecules so they can be used in an external circuit. Channels etched into the anode disperse the hydrogen gas equally over the surface of the catalyst.

The Cathode — the positive side of the fuel cell — also contains channels that distribute the oxygen to the surface of the catalyst. It conducts the electrons back from the external circuit to the catalyst where they can recombine with the hydrogen ions and oxygen to form water.

The Polymer Electrolyte Membrane — or PEM — is a specially treated material that looks something like ordinary kitchen plastic wrap that conducts only positively charged ions and blocks the negatively charged electrons. The PEM is the key to fuel cell technology as it permits only the necessary ions (molecules stripped of their electrons) to pass between the anode and cathode. The thickness of the membrane varies, depending on the catalyst and the amount of platinum (Pt) that is used in each electrode.

Image Credit - Wikipedia



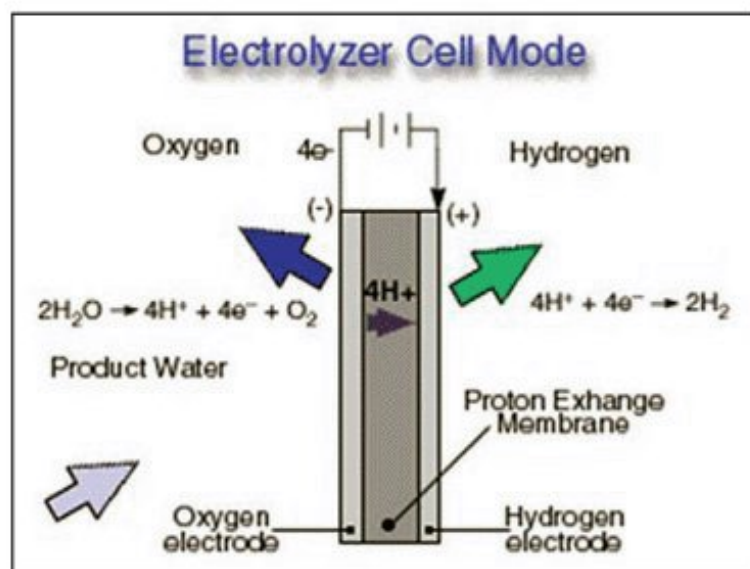


Figure 2. Electrolysis Mode.

- Total reaction: $2\text{H}_2\text{O} \rightarrow 2\text{H}_2 + \text{O}_2$ (twice H_2 versus O_2)

In Fuel Cell Mode (**Figure 3**), the process is reversed along with the polarities of the anode and cathode. As hydrogen flows into the fuel cell on the anode (negative) side of the MEA, the platinum catalyst facilitates the separation of the hydrogen gas into electrons and protons (hydrogen ions). The hydrogen ions pass through the membrane and combine with oxygen and electrons on the cathode (positive) side producing water. The electrons – which cannot pass through the membrane – flow from the anode to the cathode through an external load which consumes the power generated by the cell. The overall electrochemical process of a fuel cell is called “reverse electrolysis,” or the opposite of electrolyzing water to form hydrogen and oxygen. Once again, here are the chemical reactions:

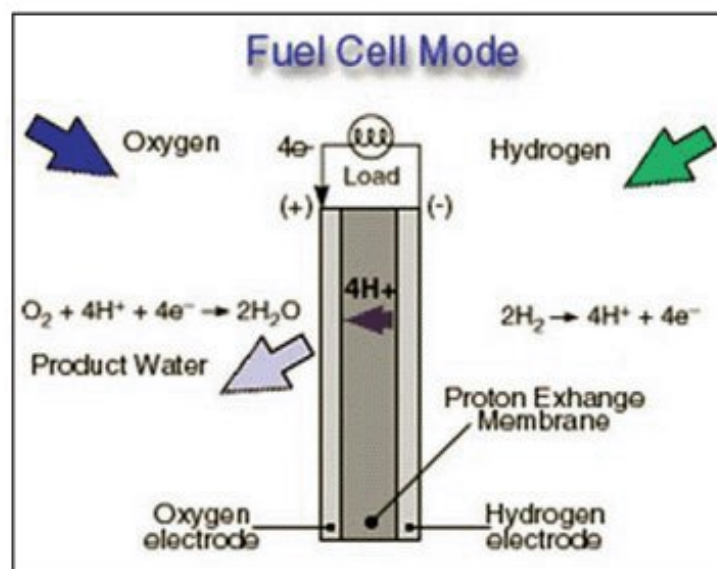


Figure 3. Fuel Cell Mode.

Fuel Cell Mode Reactions

- Anode reaction: $2\text{H}_2 \rightarrow 4\text{H}^+ + 4\text{e}^-$
- Cathode reaction: $4\text{H}^+ + 4\text{e}^- + \text{O}_2 \rightarrow 2\text{H}_2\text{O}$
- Total reaction: $2\text{H}_2 + \text{O}_2 \rightarrow 2\text{H}_2\text{O}$ (back to water again)

Experiment Setup

There’s obviously a lot more to say about fuel cell technology, but the best way to learn about it is through experimenting with it. For our reversible fuel cell, I’ve chosen one manufactured by Horizon Fuel Cell Technologies that comes in a neat little package called the Hydrocar (**Figure 4**). It has everything you’ll need to do all of the experiments, plus it’s a car and is one of the least expensive and most versatile ones on the market without sacrificing quality by any means. We’ll use it for this and the following two fuel cell articles in this series. If you have another kind



Figure 4. Horizon Hydrocar.

of hydrogen reversible fuel cell you’re of course free to use it.

To measure everything, we will use our familiar Parallax BS2 or PICAXE 28X2 circuits (**Figure 5** and **Figure 6**, respectively). You can find the complete materials required and experiments for both circuits on my website at www.learnonline.com → Experimenter Kits → BS2 or 28X2 → Hydrogen Experiments.

Before we get started with the experiments, however, you should first “hydrate” your fuel cell so that it is ready to produce maximum voltage and current. You’ll find these instructions in your fuel cell User Manual. Also, please adhere to the safety precautions that are always important for proper use; these are in the fuel cell’s manual, as well.

Electrolysis Mode

We’ll start the experiment by

Figure 5. Parallax BS2 Electrolysis Mode Schematic.

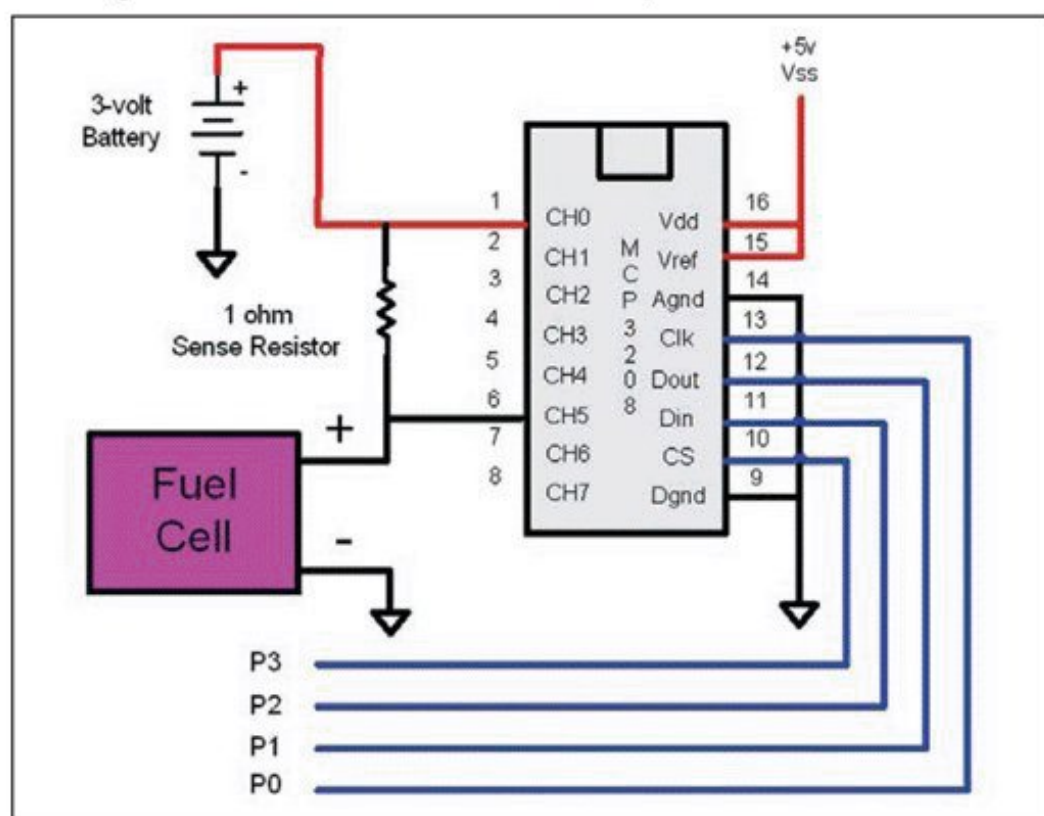


Figure 6. PICAXE 28X2 Electrolysis Mode Schematic.

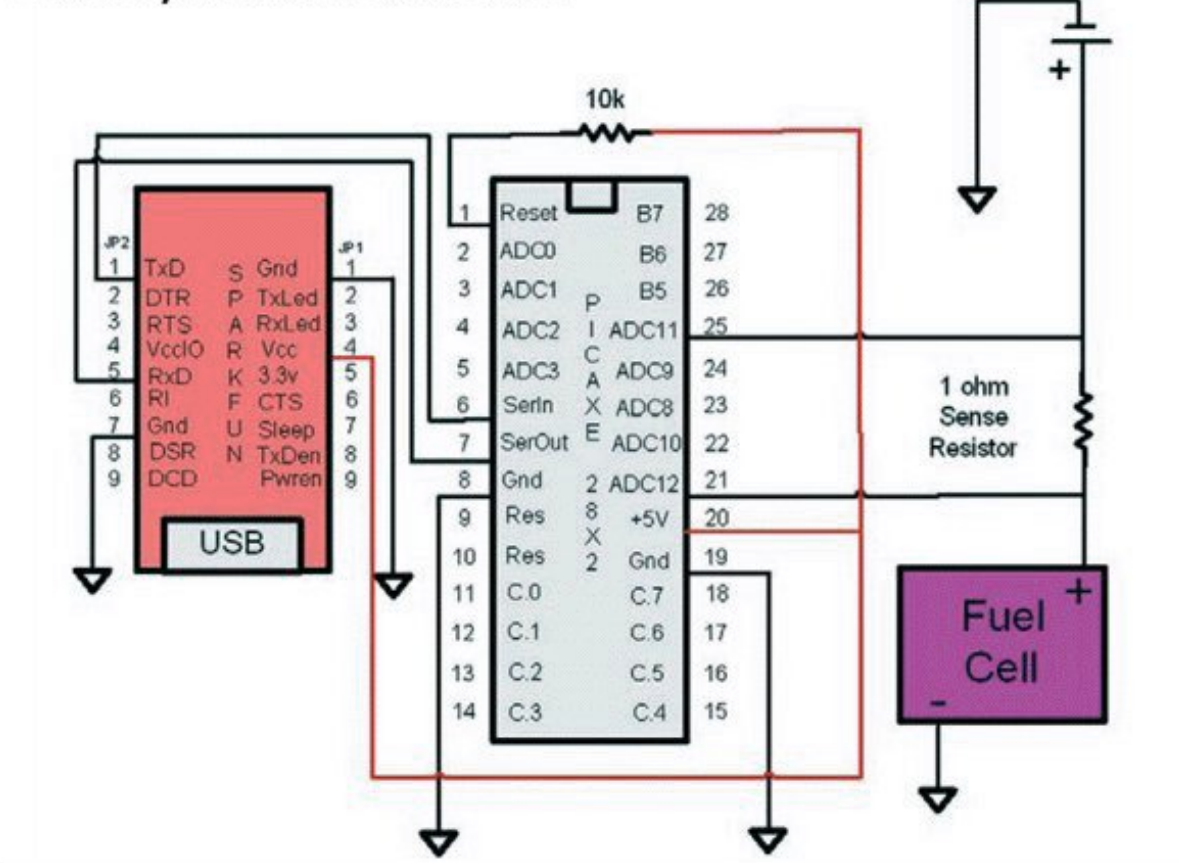




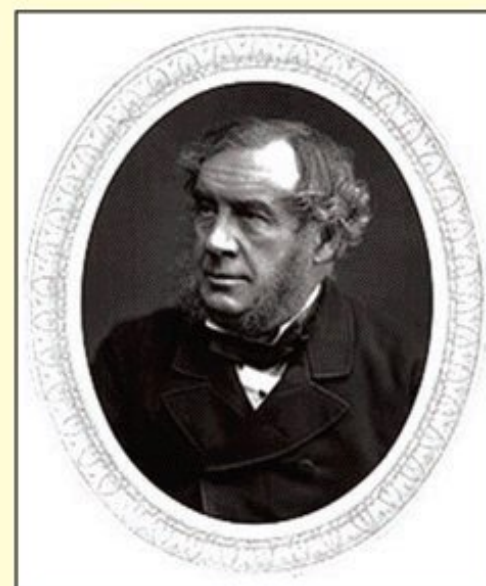
Figure 7. Hydrocar H2 - O2 Storage Tanks.

electrolyzing water into hydrogen and oxygen. After you've set up the BS2 or 28X2 circuits (don't connect the battery or solar panel yet), fill each of the two cylinders with distilled water up to the 10 ml line (**Figure 7**). Also, raise the car's wheels so they don't touch the floor or table, and purge any residual hydrogen in the system as it will affect the results. Notice that we are not connecting the reversible fuel cell to the car's motor at any point in this experiment. This is because the motor presents a variable resistance to the fuel cell as it spins, and I want to avoid this for now; we'll get to this in a future article.

With the REEL Power software running on your Windows PC, attach the three volt battery or solar panel to the circuit and witness a plot similar to **Figure 8**. If you use a solar panel, it will take much longer to electrolyze the water as the solar panel can't deliver the same level of current. (Of course, you're free to do so if you wish.) As you can see, electrolysis starts with nearly a

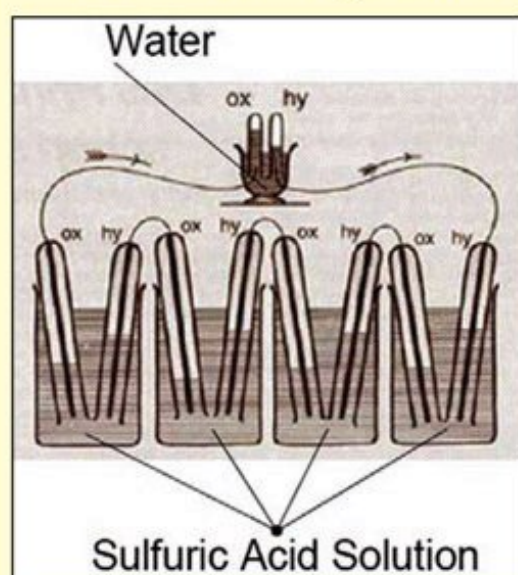
A Little Fuel Cell History

The first known fuel cell can trace its roots back to the 1830s when a Welsh born, Oxford educated barrister named Sir William Robert Grove (1811–1896) who practiced patent law and also studied chemistry (or "natural science" as it was known at the time,) realized that if electrolysis — using electricity — could split water into hydrogen and oxygen, then the opposite should also be true. That is, combining hydrogen and oxygen with the correct method would produce electricity. Sir William was right and the first fuel cell was born. It never went much beyond the laboratory stage for over a hundred years, however.



Fast-forwarding to the early 1960s, a new

government agency was about to undertake the next step in maturing fuel cell technology. NASA was developing mission-critical systems for the first prolonged manned flight into space; once in space, the orbiter needed a source of electricity. Batteries were ruled out due to their size, weight, and toxicity necessary to support a mission of eight days in space. Solar panels were also not practical at the time due to their size, weight, and low energy output (about 4% efficiency). The once obscure fuel cell thus became the technological solution to NASA's dilemma of how to provide reliable "always on" power for extended missions into space. The



PEM fuel cell was invented in the early 1960s by two General Electric scientists and was used in the Gemini series of spacecraft. It was replaced by alkaline fuel cells for the Apollo program, as well as the Space Shuttle. On the early missions — especially Apollo 13 — there were problems with fuel cells, but on subsequent missions fuel cells became increasingly more reliable.

Image Credits - Wikipedia



short-circuit as the reversible fuel cell begins to split water into hydrogen and oxygen. The internal resistance of the PEM begins to rise rapidly allowing a higher voltage and more current from the battery or solar panel to flow into the device.

Figure 9 shows the stabilization of

the Electrolysis Mode as the electrolyzing voltage, current, and power level off.

Notice it takes about 1.4 volts for the electrolysis process to work; this voltage is important for a later experiment. **Also, don't use a voltage much over three volts. Otherwise, it**

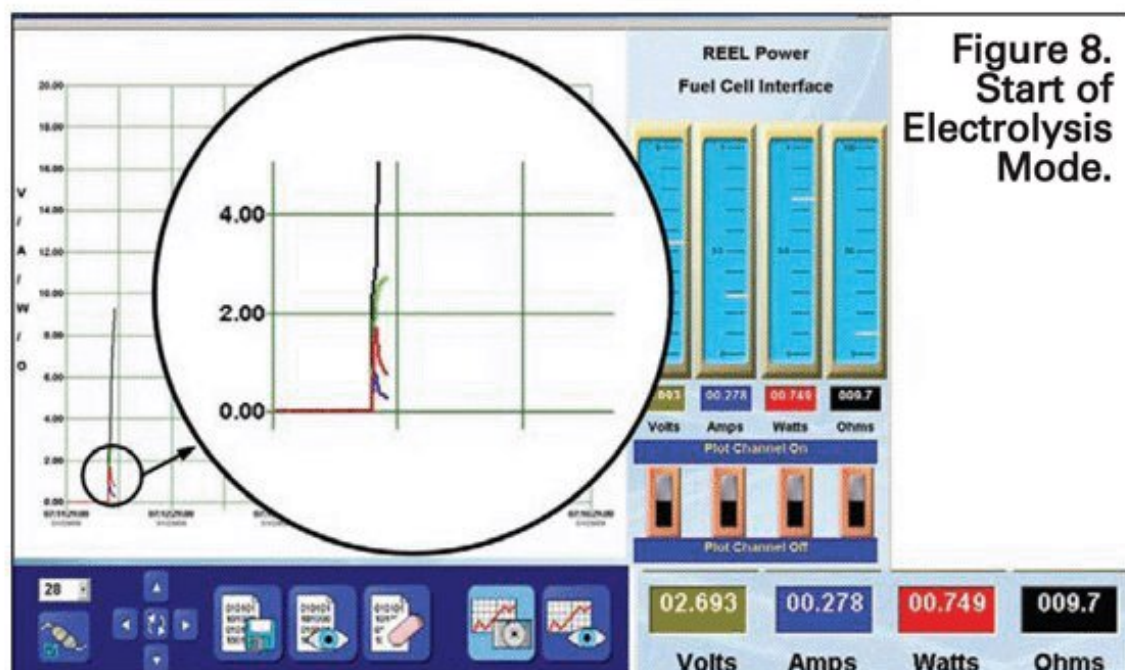


Figure 8. Start of Electrolysis Mode.

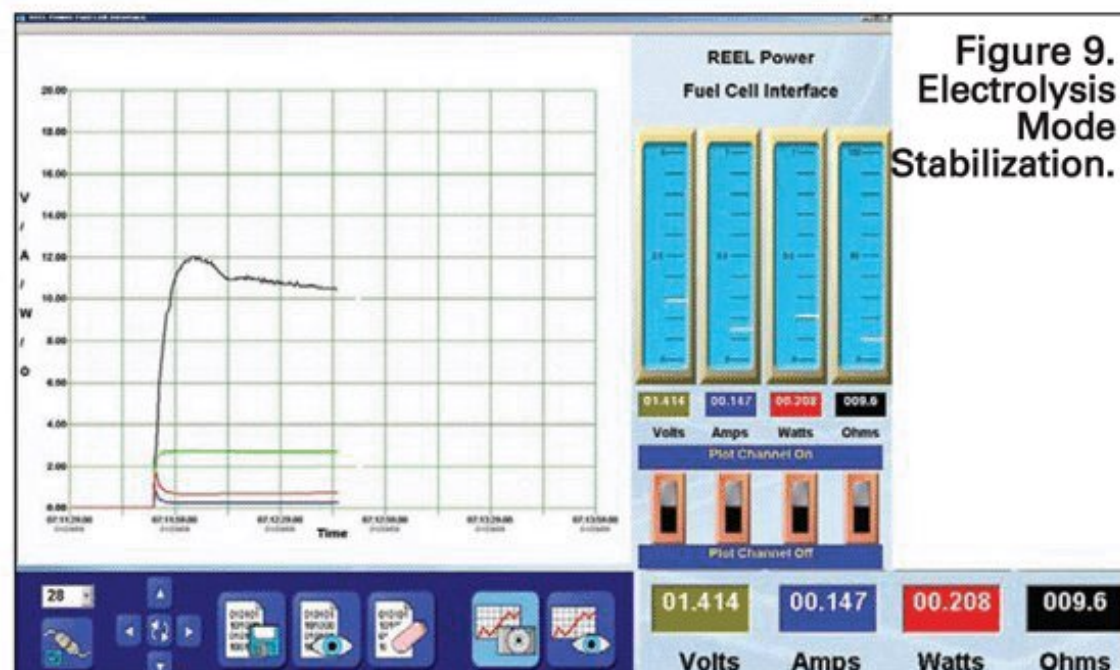


Figure 9. Electrolysis Mode Stabilization.

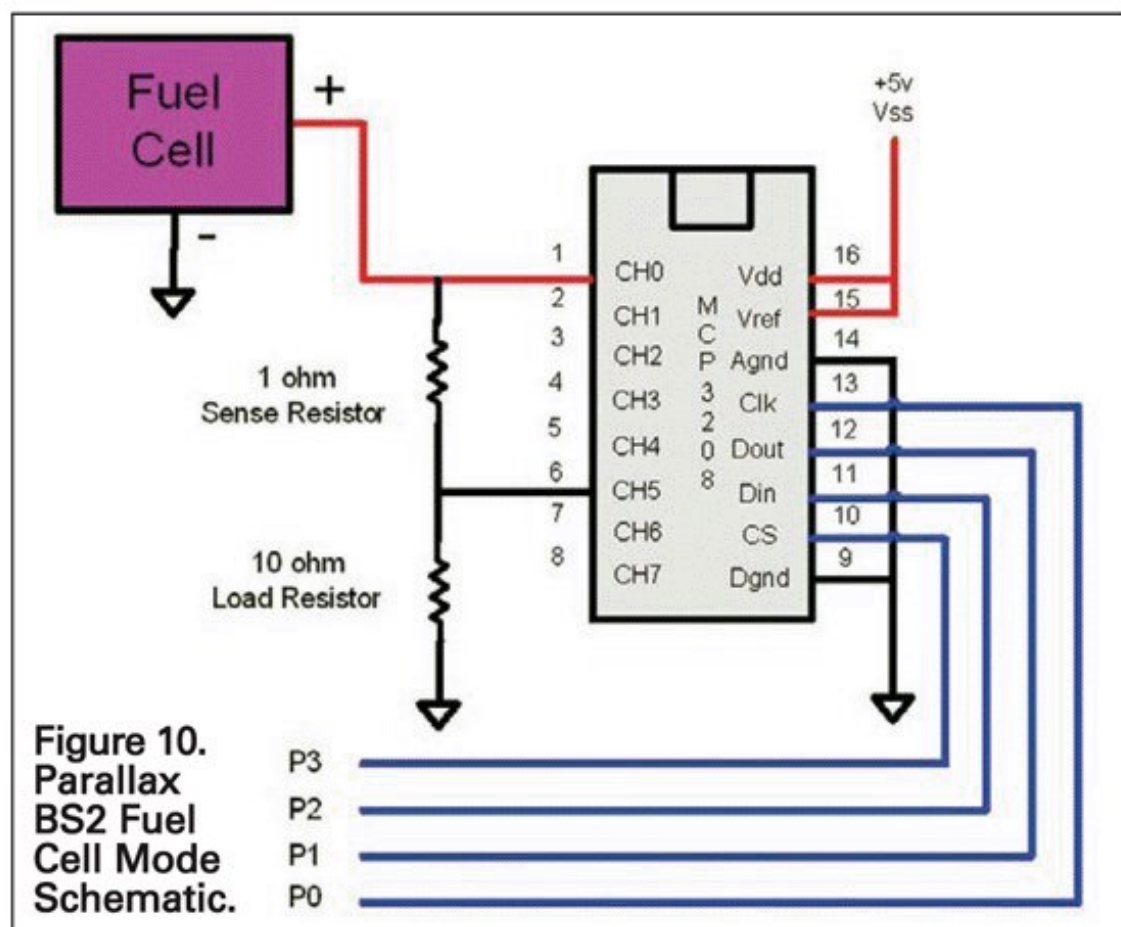


Figure 10.
Parallax
BS2 Fuel
Cell Mode
Schematic.

may damage the fuel cell. Allow the process to continue until 20 ml of hydrogen are produced. Then, remove the battery or other power source from the setup. If you're using another fuel cell and you need to clamp off the hydrogen from escaping, do so now. Notice that the level of hydrogen in its cylinder is twice that of oxygen, which confirms the 2-to-1 ratio in the familiar H_2O symbol.

Fuel Cell Mode

Now we need to reconfigure our microprocessor setup to remove the battery or solar panel and replace it with the fuel cell as the power source (but don't attach the fuel cell just yet). We also want to add a 10 ohm load resistor where the fuel cell used to be. Again, don't connect the motor to the fuel cell as a load. Refer to **Figure 10** and **Figure 11** for these

new schematic hookups. Once again with the REEL Power software running, attach the fuel cell to the circuit and witness a plot similar to **Figure 12**. This is the transition from Electrolysis to Fuel Cell Mode. Notice the voltage, current, and power drops as the fuel cell now begins to deliver its stored energy into the 10 ohm load.

Figure 13 illustrates just how well the fuel cell performs over an extended period of time delivering a constant voltage and current into the load. This is important in that as long as hydrogen fuel is available, the voltage and current outputs remain constant. This is quite similar to the modern lithium and nickel metal hydride batteries we studied in Part 3. Also notice that the average voltage output from the fuel cell is about 0.6 volts; this is the norm for hydrogen PEM fuel cells.

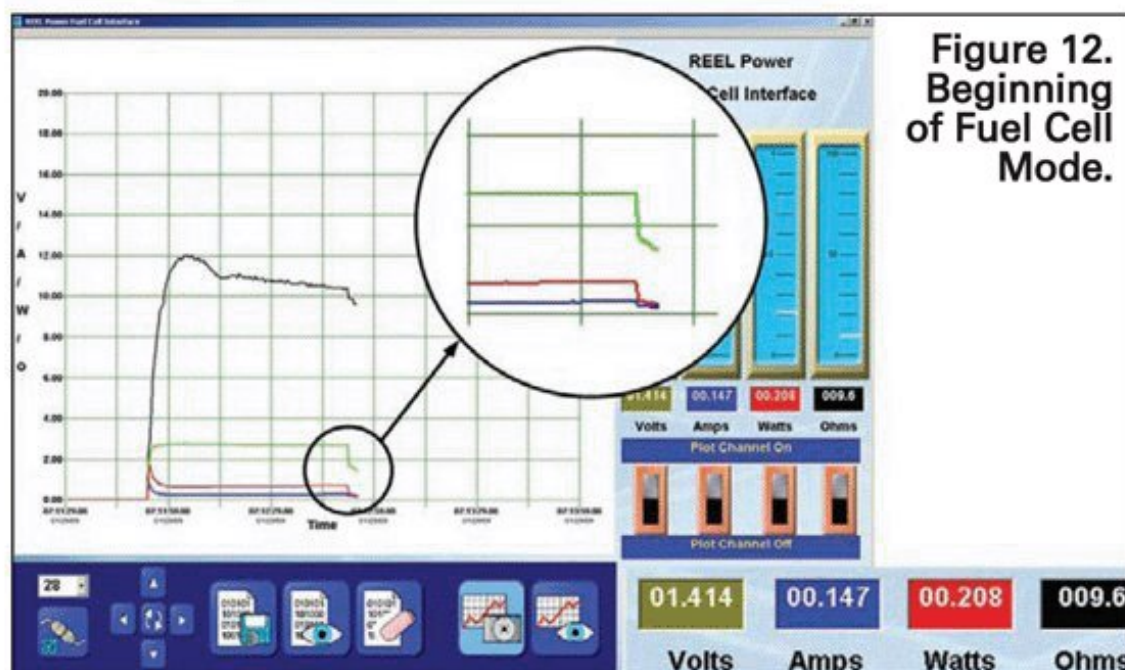


Figure 12.
Beginning
of Fuel Cell
Mode.

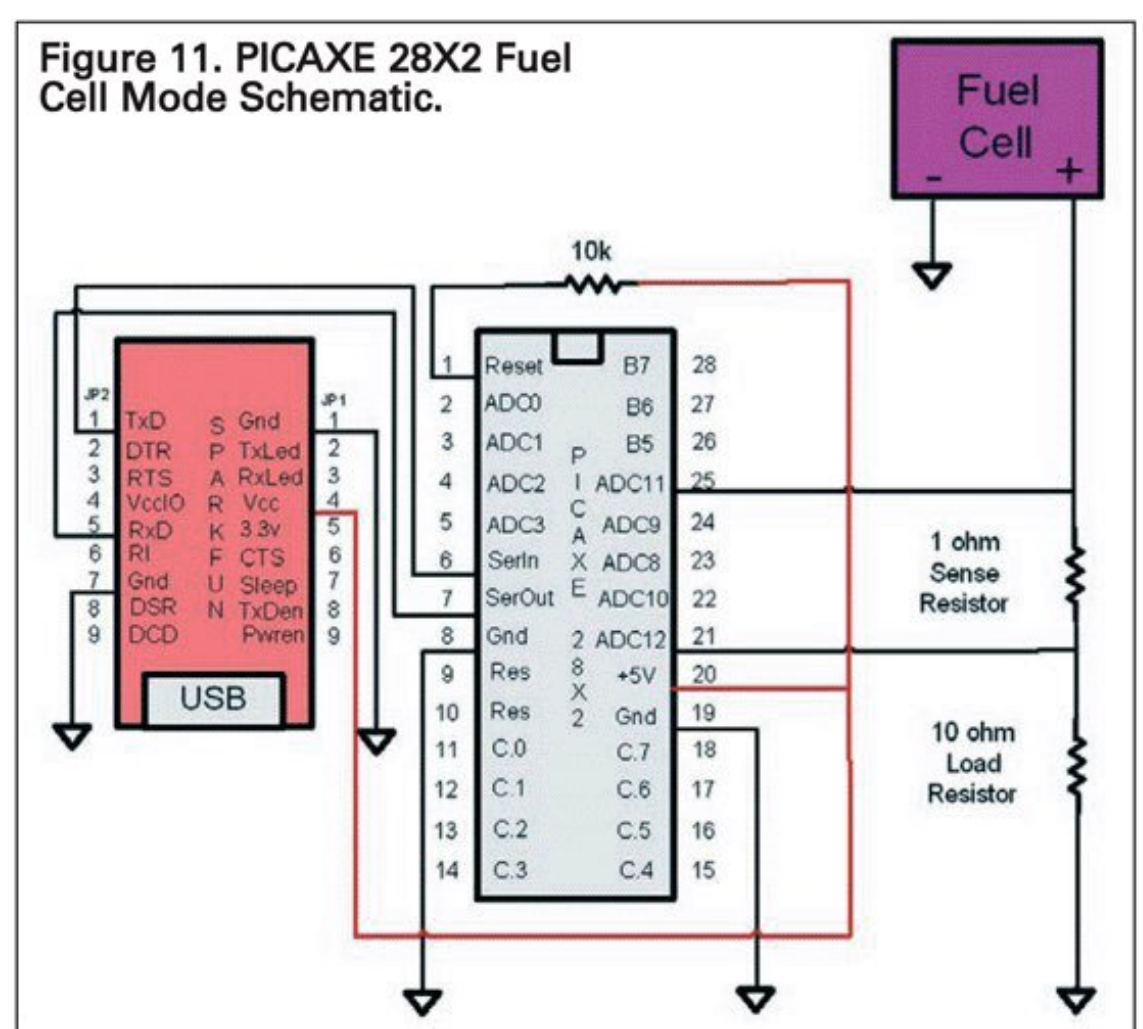


Figure 11. PICAXE 28X2 Fuel
Cell Mode Schematic.

Allow the entire amount of hydrogen to be consumed as we want to be able to start fresh with our next experiment.

Determining the Water Decomposition Voltage

I mentioned earlier that there was a minimum voltage necessary to separate hydrogen and oxygen called the Water Decomposition Voltage. The theoretical voltage is 1.23 volts DC; however, it's higher in actual practice due to impurities in the electrolysis process. The difference between the theoretical decomposition voltage and the measured voltage is called "*overpotential*."

Overpotential is a function of the

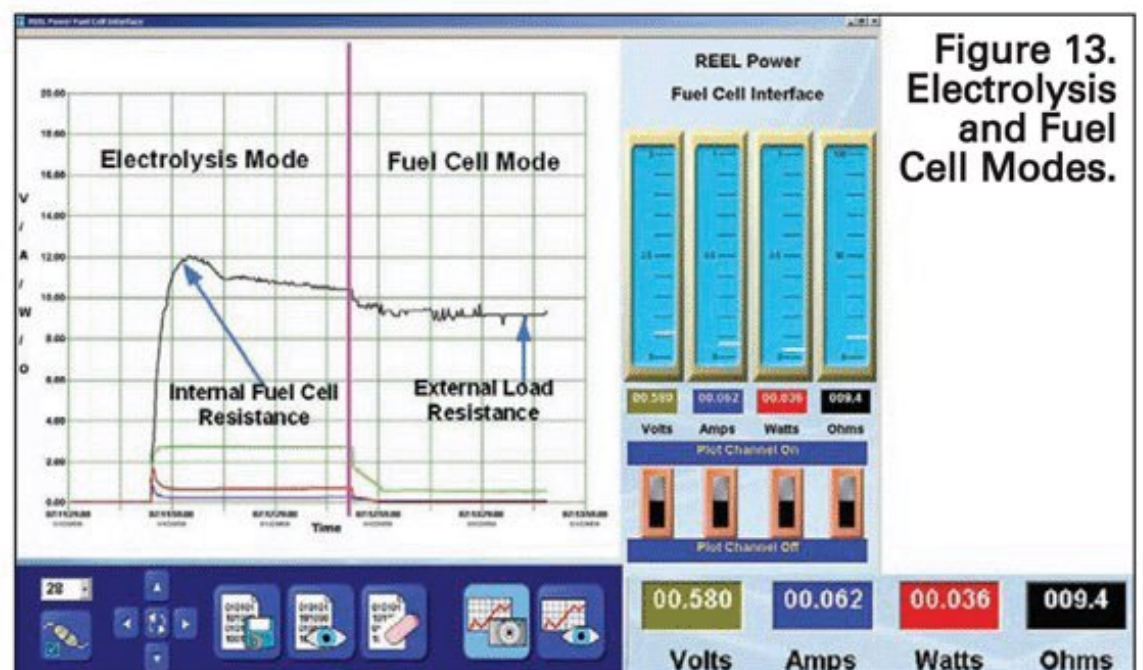


Figure 13.
Electrolysis
and Fuel Cell
Modes.

minimum voltage where electrolysis begins.

Figure 16 illustrates that our minimum voltage is 1.47 volts where a minimum current of 24 milliamps is flowing. More voltage will result in a lower internal resistance that allows for more current to flow as shown in **Figure 17**.

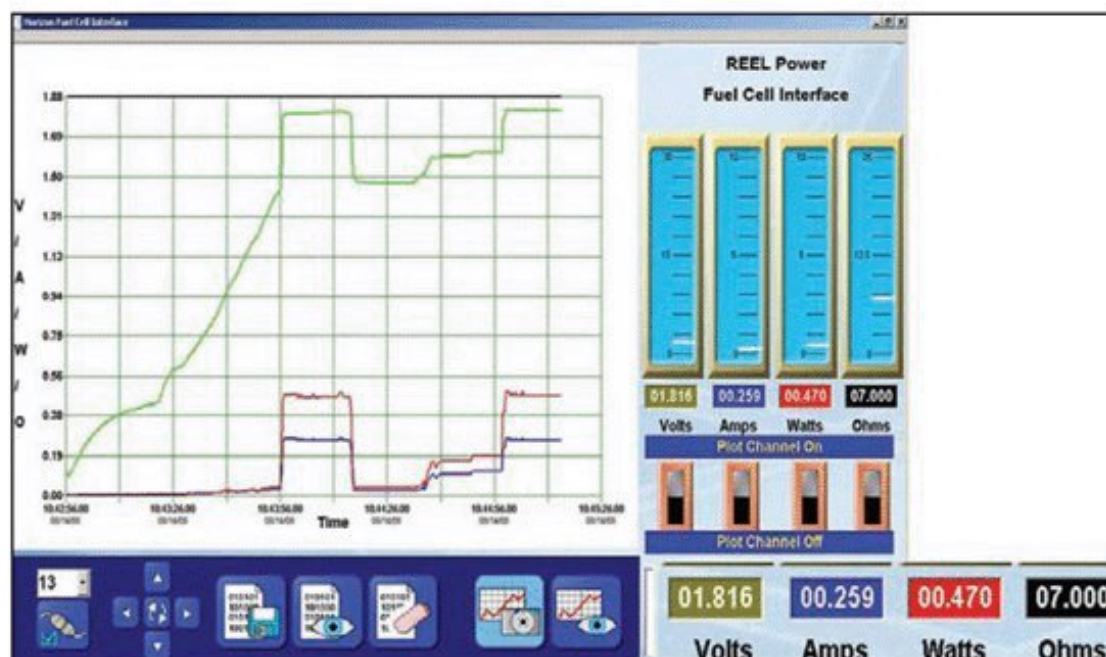
Summary

In this first article, you were introduced to some of the fuel cell's basic operational characteristics like the dual modes of operation and minimum water decomposition voltage. Future articles will address more of its inner workings, as well as applications for portable electronics and for powering vehicles. If recent history is any guide, the fuel cell will most likely gain greater prominence in the coming years. For example, the first decade of the 21st century lead the way to the expansion of the Internet and the "always connected generation" with Internet-enabled portable computers and cell phones.

The second decade will most likely lead to independent, portable power sources that run off grid and produce little or no pollution – plus be economically competitive and ready to use 24/7. Fuel cells will be a big part of this. If that sounds impractical or a bit too optimistic, then just look back 10 years to see what's happened

Figure 17. Adding More Voltage For Greater Electrolysis.

to computer and communications technologies in that short amount of time. We shall see. In the meantime conserve energy and "stay green." **NV**



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■ BY FRED EADY

SHUFFLING THE TCP/IP STACK

Just a few minutes after finishing up last month's ZeroG column, I realized that the seemingly simple 16-bit PIC24FJ128GA006 microcontroller design contains a ton of potential. I've been doing some really deep thinking about how to tap that potential. So this month, in addition to shuffling bits in the Microchip TCP/IP stack, we're going to perform some soldering iron surgery.

WALKING THE MICROCHIP TCP/IP STACK

The Microchip TCP/IP Stack is designed to accommodate all of the currently available Microchip Ethernet products. However, the Microchip TCP/IP Stack architects also realized that when it comes down to hardware designs, not everyone would be following Microchip's yellow brick road. So, they left some really obvious back doors and windows open for those of us skipping around in ruby red slippers behind a little yip-yip dog.

Although the PIC18, PIC24, and PIC32 families of microcontrollers are supported by the TCP/IP Stack, the 16-bit PIC24FJ128GA006 we used in the ZG2100M support role is not directly supported in any of the Stack templates. Recall that during the design of the ZeroG support hardware, we attempted to address the ZeroG module in a similar manner to other 16-bit microcontrollers supported by the TCP/IP Stack. So, when we could, we used the same microcontroller I/O pin-to-ZG2100M-scheme as laid out in the Stack's configuration files.

Regardless of our copy cat ways, one of the very first things we need to do is inform the TCP/IP Stack that we are "different." We can identify ourselves to the stack components by way of the Stack's HardwareProfile.h file. Here's how the Stack architects have allowed us to introduce ourselves:

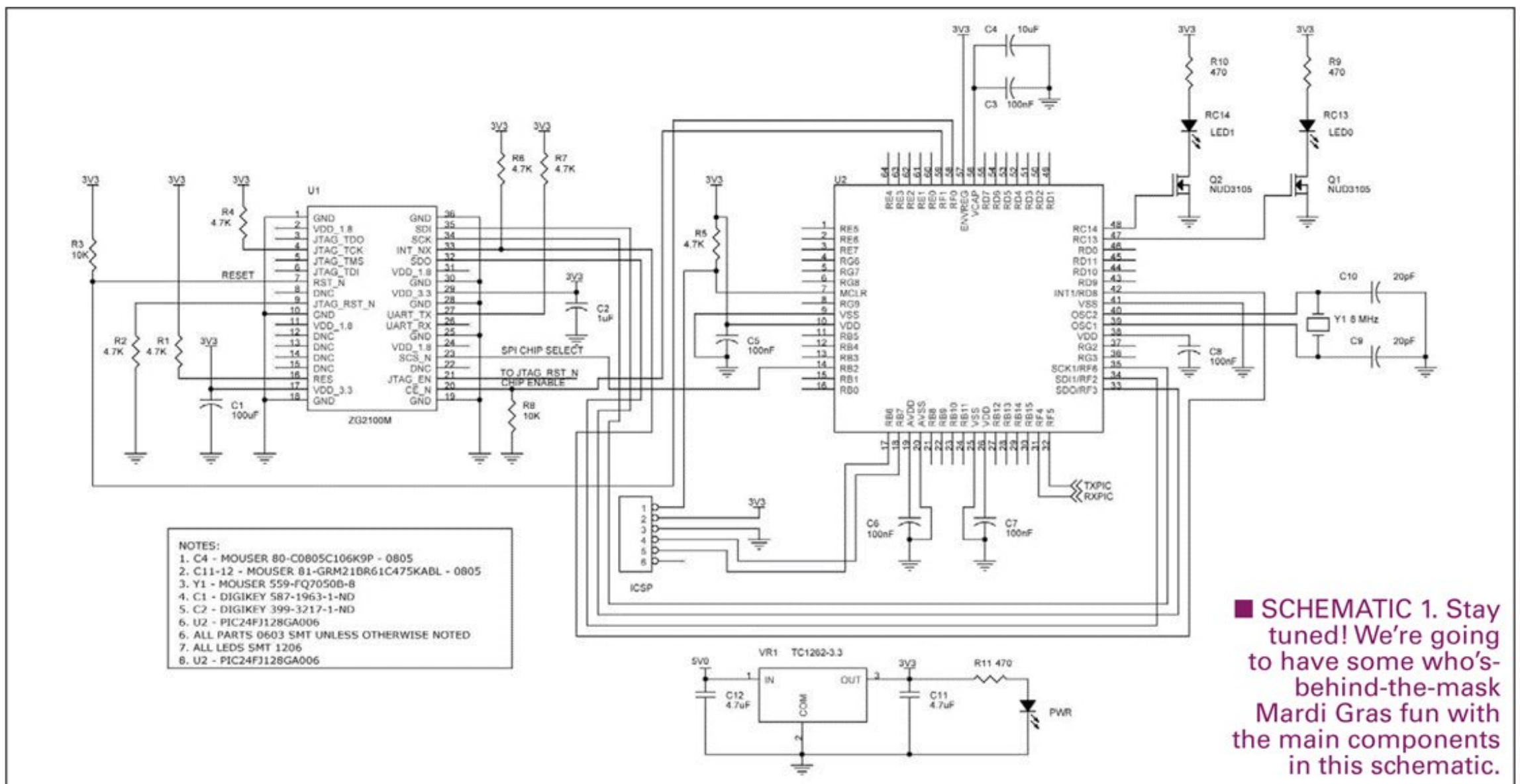
```
// Choose which hardware profile to compile for
// here. See the hardware profiles below for
// meaning of various options.
#define PICDEMNET2
#define PIC18_EXPLORER
#define HPC_EXPLORER
#define PIC24FJ64GA004_PIM
#define EXPLORER_16
#define DSPICDEM11
#define PIC32_STARTER_KIT
#define PIC32_ETH_STARTER_KIT
#define YOUR_BOARD
#define ZeroG_PIC24FJ128GA006_TRAINER
```

Choosing a hardware profile entails removing the comment prefix (//). Naturally — to avoid compiler apocalypse — we should only select a single profile from the list. The PIC24FJ64GA004 PIM is designed to mount in the Explorer 16 Development Board's PIM socket. However, due to the PIC24FJ64GA004 PIM module's significantly different pin mappings, this particular PIM has its own set of stack definitions. Most of the other Explorer 16 Development Board PIMs are supported by the TCP/IP Stack under the EXPLORER_16 definition. These devices include the PIC24FJ128GA010, the PIC24HJ256GP610, the dsPIC33FJ256GP710, the PIC32MX360F512L, the PIC32MX460F512L, and the PIC32MX795F512L PIMs.

The Microchip 32-bit microcontroller starter kits are also supported by the TCP/IP Stack. The PIC32MX starter kits supported under the PIC32 STARTER KIT definition include the PIC32MX360F512L Starter Kit, the PIC32MX460F512L USB Starter Board, and the PIC32MX795F512L USB Starter Kit II. There's even specialized stack support for the PIC32MX795F512L Ethernet Starter Kit board.

YOUR_BOARD is really our board, which is the ZeroG PIC24FJ128GA006 Trainer we constructed last month. If we had not defined a chunk of target hardware, the Stack will get up on its donkey and start making assumptions while looking for clues as to what microcontroller it will be compiled to drive. The most obvious place to begin looking is in the area of MPLAB IDE that specifies the microcontroller type to the IDE. Obviously, our life with the Stack is much easier if we don't allow it to go donkey walk-about.

According to **Schematic 1** and the ExpressPCB layout in **Figure 1**, the ZeroG - PIC24FJ128GA006 Trainer has a couple of user-accessible LEDs hanging out there on I/O pins RC13 and RC14. As my mom would say, "That's nice." However, our stack application doesn't know about them unless we tell it that they are available. The same Stack ignorance holds true for the clock frequency that is driving the Trainer's PIC24FJ128GA006 microcontroller. When we defined our Trainer to the Stack earlier, we were also given



the privilege to carve out some configuration definition space of our own within the confines of HardwareProfile.h:

```
#elif defined(ZeroG_PIC24FJ128GA006_TRAINER)
// Define your own board hardware profile here
// PIC24F processor
#define GetSystemClock() (32000000ul) // Hz
#define GetInstructionClock()
    (GetSystemClock()/2)
#define GetPeripheralClock()
    GetInstructionClock()

#define LED0_TRIS    (TRISCbits.TRISC13)
#define LED0_IO      (LATCbits.LATC13)
#define LED1_TRIS    (TRISCbits.TRISC14)
#define LED1_IO      (LATCbits.LATC14)
// no other LED's
#define LED3_TRIS    LED1_TRIS
#define LED3_IO      LED1_IO
#define LED4_TRIS    LED1_TRIS
#define LED4_IO      LED1_IO
#define LED5_TRIS    LED1_TRIS
#define LED5_IO      LED1_IO
#define LED6_TRIS    LED1_TRIS
#define LED6_IO      LED1_IO
#define LED7_TRIS    LED1_TRIS
#define LED7_IO      LED1_IO
#define LED_GET()    (*(volatile unsigned
    int*)&LATC))
#define LED_PUT(a)   (*(volatile unsigned
    int*)&LATC) = (a)
```

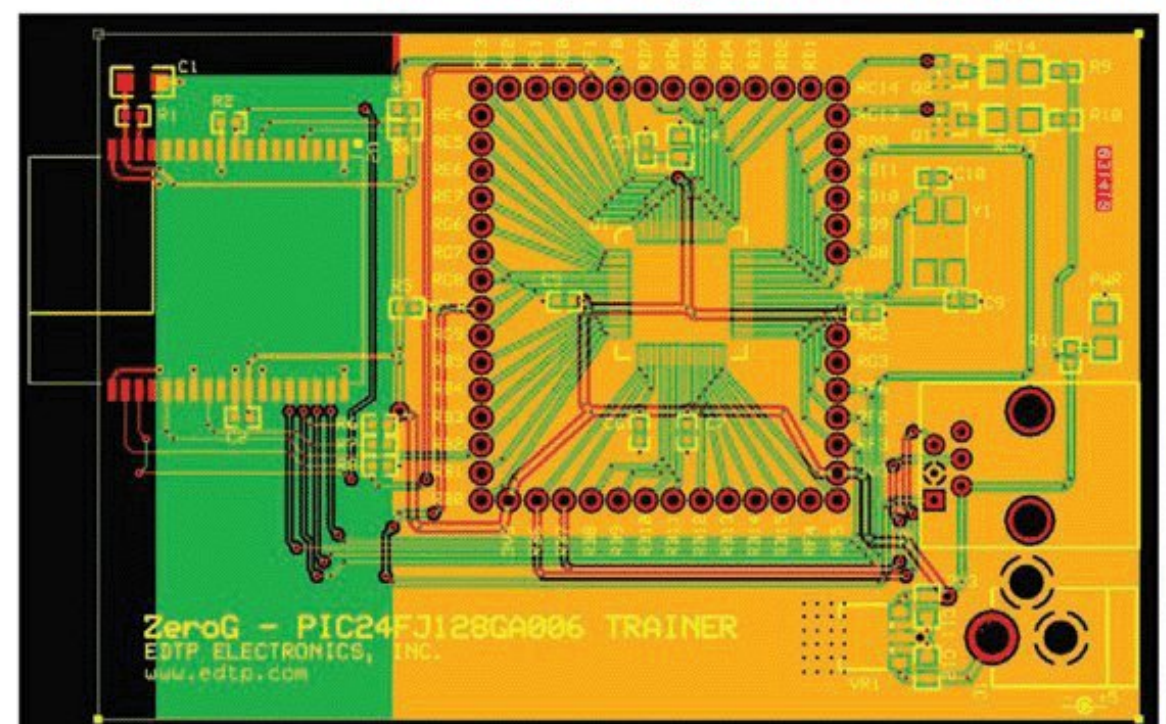
The pair of user LEDs and the clocking scheme are exposed to the rest of the stack components in our ZeroG Trainer HardwareProfile.h definition space. Note that since we only have a pair of LEDs and the Stack is expecting to see a few more, we must dummy up on nonexistent LEDs that may be expected to be there by other modules that comprise the TCP/IP Stack. Our definition coding references any calls to nonexistent LEDs to our LED1. Any LED

beyond LED1 that is referenced in the Stack will resolve to LED1. The absence of the LEDs beyond LED1 won't keep the Stack from functioning. However, trust me. You will grow weary of fixing the undefined LED compile errors. Our MainDemo.c application file wants to blink LED0 to let us humans know that the Stack code is running:

```
// Blink LED0 (right most one) every second.
if(TickGet() - t >= TICK_SECOND/2ul)
{
    t = TickGet();
    LED0_IO ^= 1;
}
```

The Stack creators have thrown us a bone here with the gift of the LED_GET and LED_PUT macros.

FIGURE 1. This is a graphic depiction of the ZeroG - PIC24FJ128GA006Trainer ExpressPCB layout file. You can get the actual ExpressPCB file from within this month's download package at www.nutsvolts.com.





Some of the TCP/IP Stack example applications like to have their buttons pushed. Our Trainer hardware is button free, but our Trainer TCP/IP Stack definitions are not:

```
#define BUTTON0_TRIS (TRISBbits.TRISB12) // Ref
// S4
#define BUTTON0_IO (PORTBbits.RB12)
```

The buttons on the Explorer 16 Development Board are mapped to PORTD. It doesn't matter where we map our button (or buttons) just as long as the buttons follow the TCP/IP Stack naming convention. For instance, BUTTON0 is BUTTON0 no matter if it is mapped to RB12 or RF0.

The ZG2100M module feeds from a SPI portal. To keep things as simple as possible and to follow the predetermined flow of the TCP/IP Stack, we must map the PIC24FJ128GA006's SPI portal to the ZG2100M's SPI portal exactly like the TCP/IP Stack does. In that the PIC24FJ128GA006's or any other SPI-equipped PIC's hardware SPI portal is represented by a standard set of PIC microcontroller pins, we can easily map the PIC24FJ128GA006 to the ZG2100M's SPI pin set in our section of the HardwareProfile.h file:

```
//-----
// ZeroG ZG2100M WiFi I/O pins
//-----

#define ZG_CS_TRIS (TRISBbits.TRISB2)
#define ZG_CS_IO (LATBbits.LATB2)
#define ZG_SDI_TRIS (TRISFbits.TRISF2)
#define ZG_SCK_TRIS (TRISFbits.TRISF6)
#define ZG_SDO_TRIS (TRISFbits.TRISF3)
#define ZG_RST_TRIS (TRISFbits.TRISF0)
#define ZG_RST_IO (LATFbits.LATF0)
#define ZG_EINT_TRIS (TRISDbits.TRISD8) // INT1
#define ZG_EINT_IO (PORTDbits.RD8)
#define XCEN33_TRIS (TRISFbits.TRISF1)
#define XCEN33_IO (PORTFbits.RF1)
```

You can check the HardwareProfile.h SPI portal entries against the actual circuit routes in **Schematic 1**. What you can't see in **Schematic 1** are the ZG2100M interrupt definitions which are also part of our HardwareProfile.h definitions:

```
#if defined( __C30__ )
#define ZG_EINT_EDGE (INTCON2bits.INT1EP)
#define ZG_EINT_IE (IEC1bits.INT1IE)
#define ZG_EINT_IF (IFS1bits.INT1IF)
```

The __C30__ definition tells us that the interrupt bits that follow it will be used if the MPLAB C Compiler for PIC24 MCUs is being used to compile our TCP/IP Stack application. In our case, the #if will return a Boolean true.

We've had quite a few TCP/IP discussions and the Stack has been at the center of many of them. If you've been privy to those discussions, you already know that we don't have to do a bunch of coding to utilize the built-in features of the Stack. Many of the routines that would normally be written in the Stack application are already functions that are permanent, precoded members. So, in addition to coding our Stack application, all we really need to do to put it to work is twiddle a few bits in the HardwareProfile.h

and TCPIPConfig.h files. Our Trainer design takes advantage of the Stack's ZG2100M drivers and support functions. We're about to see just how easy it is to add an LCD and RS-232 interface to our ZeroG Trainer design.

ADDING A REGULATION RS-232 HARDWARE INTERFACE

The TCP/IP Stack can talk to us via the Trainer's RS-232 port. However, as you can see in **Schematic 1**, there is no Trainer RS-232 port. That's partly because the PIC24FJ128GA006's SPI1 portal is being used instead of assigning the SPI SDI1 and SDO1 pins as UART I/O pins U1RX and U1TX. Fred's First Rule of Embedded Computing states that in the world of embedded design, nothing is free. Not to worry. The Stack is also capable of utilizing the PIC24FJ128GA006's second UART on I/O pins RF4 and RF5. Before we can pass RS-232 traffic through the second UART, we have some soldering to do.

The header pads surrounding the PIC24FJ128GA006 in **Figure 1** are all placed on 0.1 inch centers. Doing this allows us to mate the Trainer's PCB (printed circuit board) to an auxiliary PCB or breadboard using inexpensive 0.1 inch pitch SIP (Single Inline Package) header pins and header sockets. As you can see in **Photo 1**, I've chosen to equip the Trainer's PCB with the 0.1 inch center header pins. The female socket pins are mounted on a Twin Industries 8100-45-LF prototyping board lying under the CANON in **Photo 2**. The 8100-45-LF is a 4.0 inch x 5.0 inch gold-plated, FR4-based prototyping board with 0.37 inch plated holes. I mounted the Trainer PCB in the upper left corner of the 8100-45-LF prototyping board to meet the RF radiation clearance requirements of the ZG2100M Ethernet module that is integral to this PCB.

The PIC24FJ128GA006's digital input I/O pins are all five-volt tolerant. However — if we can — it would be nice not to have to worry about that when we construct our UART interface circuitry. So, to keep things simple, we'll design our UART interface around the STMicroelectronics ST3232 RS-232 Driver/Receiver IC. The ST3232 is capable of operating with power supply rails as low as 3.0 volts and as high as 5.5 volts. Drawing between 0.3 mA and 1.0 mA of current during normal operation, the ST3232 can be easily accommodated by the ZeroG Trainer's onboard TC1262-3.3 voltage regulator. With that, I've added a couple of 3.30 volt electrical paths between the Trainer and the Twin Industries prototyping board.

The Trainer's RS-232 interface consists of an STMicroelectronics ST3232, five 0.1 µF ceramic capacitors, a 10-pin header, a 10-pin IDC plug, a ribbon cable, and a nine-pin female D-shell connector. I connected all of the aforementioned items together as you can see in **Schematic 2**.

The RS-232 interface design is identical to the RS-232 hardware used by the EDTP Ethernet MINI NIC. If you orient and assemble your RS-232 interface cable exactly like you see in **Photo 3**, you won't have to scratch your head or pull out that ohmmeter. My version of the RS-232

engineering change is under the lens in **Photo 4**.

DRIVING THE NEW RS-232 HARDWARE

As I mentioned earlier, the TCP/IP Stack has many built-in functions that we can take advantage of with one of those being a PIC24FJ128GA006 UART driver. We must dip into the TCPIPConfig.h file to use the built-in UART driver code:

```
// =====
// Application Options
// =====
/* Application Level Module Selection
 * Uncomment or comment the following lines to
 * enable or disabled the following high-level
 * application modules.
 */
#define STACK_USE_UART // Application demo
                        // using UART for IP
                        // address display
                        // and stack
                        // configuration
```

The stack UART code is revealed by simply removing the comment slashes shielding the #define STACK_USE_UART statement. Since we aren't using a standard PIC platform expected by the TCP/IP Stack, we must balance the UART equation in our HardwareProfile.h definitions. This involves identifying the PIC24FJ128GA006's UART2 I/O pins to the Stack:

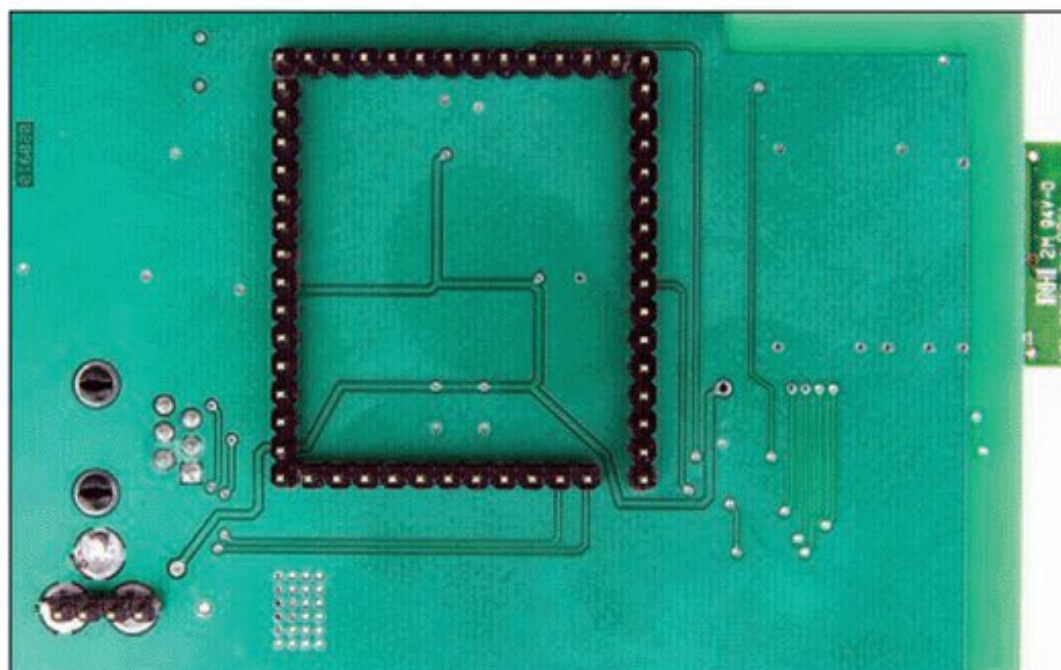
```
#define UARTTX_TRIS (TRISFbits.TRISF5)
#define UARTTX_IO (PORTFbits.RF5)
#define UARTRX_TRIS (TRISFbits.TRISF4)
#define UARTRX_IO (PORTFbits.RF4)
```

Up to this point, we've been performing some serious configuration coding. However, thus far, we haven't handled any executable UART2 code and that's a good thing because the TCPIPConfig.h and HardwareProfile.h files are configuration files. The actual UART2 code lies in a Stack file called UART.c which is included in our compilation process. The code within the UART.c file is encapsulated with this conditional compilation statement:

```
#if defined(STACK_USE_UART)
    //UART.c driver code located here
#endif
```

To be able to use any of the stack's free UART

■ **PHOTO 1.** The ZeroG - PIC24FJ128GA006 Trainer printed circuit board was designed from the ground up to allow external boards and circuitry easy access to the I/O subsystem.



SOURCES

EDTP Electronics, Inc.
ZeroG - PIC24FJ128GA006
Trainer
www.edtp.com

Microchip
PIC24FJ128GA006
TCP/IP Stack
ZeroG ZG2100M Wi-Fi Module
www.microchip.com

code, all of the UART2 functions inside of UART.c must be exposed in our Trainer section of the HardwareProfile.h file:

```
#define UBRG U2BRG
#define UMODE U2MODE
#define USTA U2STA
#define BusyUART() BusyUART2()
#define CloseUART() CloseUART2()
#define ConfigIntUART(a) ConfigIntUART2(a)
#define DataRdyUART() DataRdyUART2()
#define OpenUART(a,b,c) OpenUART2(a,b,c)
#define ReadUART() ReadUART2()
#define WriteUART(a) WriteUART2(a)
#define getsUART(a,b,c) getsUART2(a,b,c)
#define putsUART(a) putsUART2((unsigned int*)a)

#define getcUART() getcUART2()
#define putcUART(a) putcUART2(a)
do{while(BusyUART()); while(BusyUART()); }while(0)

#define putrsUART(a) putrsUART2(a)
#endif
```

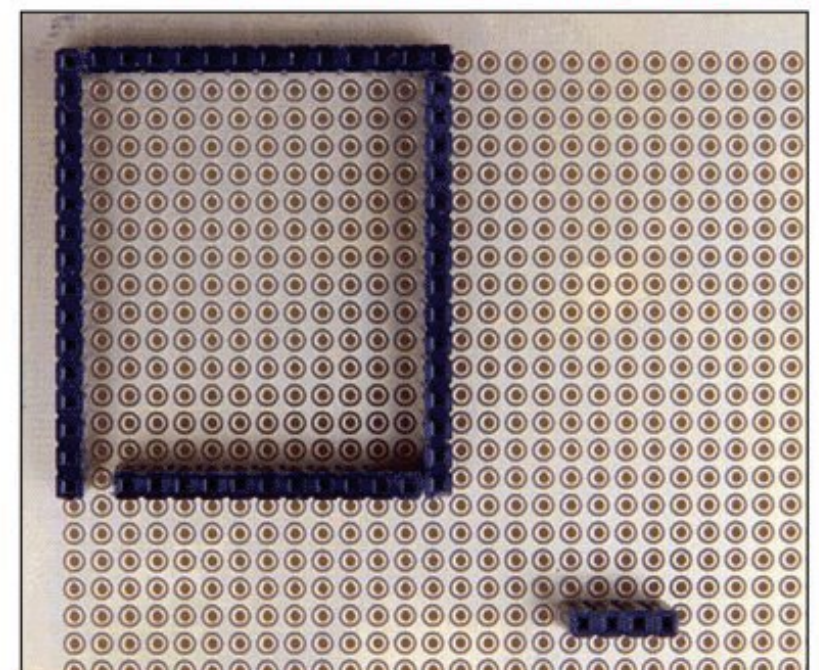
Now that you see what was exposed by our entries in the ZeroG - PIC24FJ128GA006 Trainer area of the HardwareProfile.h file, the UART2 function names provide a good idea of how the functions within the UART.c file manipulate the PIC24FJ128GA006's UART2 hardware.

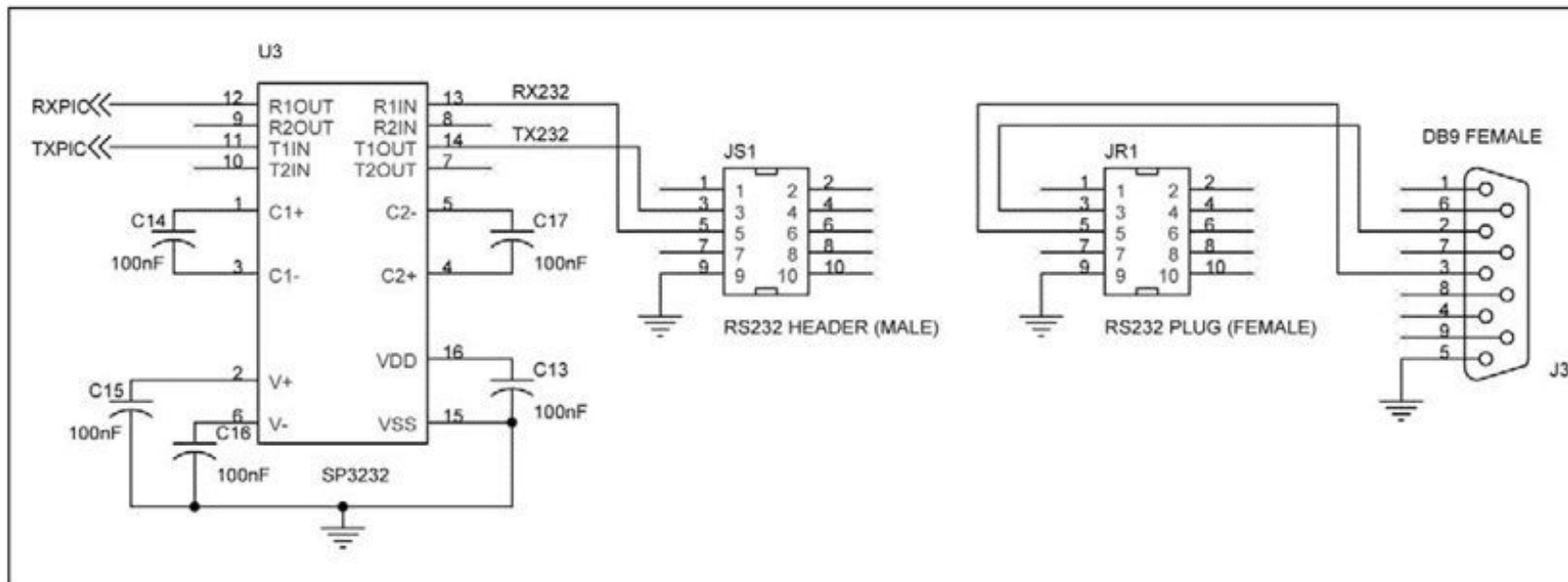
I don't want that soldering iron to go idle and cool down just yet. So, before we reap the benefits of our new RS-232 capabilities, let's perform the other engineering change.

ADDING AN LCD

I'm sure you know the drill. To integrate an LCD into our Trainer design we must first define the LCD I/O pinout in the sector of the Stack's HardwareProfile.h file. The trick

■ **PHOTO 2.** Standard perfboard will work just fine here, as well. The ground plane and plated holes make this high-quality prototyping board a top candidate for just about any breadboarding project.





■ **SCHEMATIC 2.** Installing a nine-pin shell connector on our prototype board requires the services of my Dremel MotoTool. It's cleaner to use a standard 10-pin header as the RS-232 hardware interface.

Development Board's LCD I/O map.

Judging by what we've done thus far, the next logical step would be to enable the Stack's LCD driver code from within the TCPIPConfig.h file.

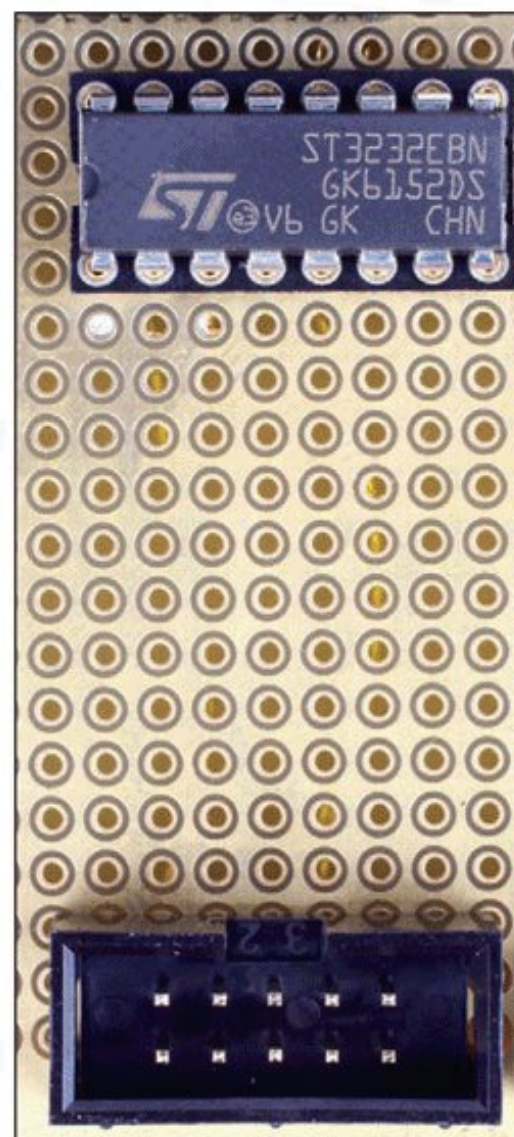
here is to choose free I/O pins on our PIC24FJ128GA006 that are suitable to be used as LCD I/O pins. Here's my take:

```
#define LCD_DATA_TRIS (*(volatile BYTE*)
                        &TRISE))
#define LCD_DATA_IO  (*(volatile BYTE*)
                        &LATE))
#define LCD_RD_WR_TRIS (TRISDbits.TRISD5)
#define LCD_RD_WR_IO  (LATDbits.LATD5)
#define LCD_RS_TRIS   (TRISBbits.TRISB15)
#define LCD_RS_IO     (LATBbits.LATB15)
#define LCD_E_TRIS    (TRISDbits.TRISD4)
#define LCD_E_IO      (LATDbits.LATD4)
```

Beating my LCD I/O pin definitions against **Schematic 1** assigns a totally unused PORTE to the LCD data bus; I/O pin RD5 is available for the LCD RD/WR I/O interface pin. It looks like RB15 is also free for duty and so are I/O

pins RD4 and RD5. I can't take all of the credit for this LCD pin map as it is identical to the Explorer 16

■ **PHOTO 3.** Assemble your ZeroG - PIC24FJ128GA006 Trainer RS-232 cable in this manner. I've already done all of the head scratching and continuity checking for you.



This situation spawns Fred's Second Rule of Embedded Computing: Never assume anything. In the case of the LCD, the enabler definition is found in the TCP/IP Stack's TCPIP.h file which should never be modified by the programmer:

```
// Enable the LCD if configured in the
// hardware profile
#if defined(LCD_DATA_IO) || defined(LCD_DATA0_IO)
    #define USE_LCD
#endif
```

It seems that we have unwittingly enabled the TCP/IP Stack's LCD driver functions by simply defining the LCD's data I/O map to the Stack in the HardwareProfile.h file. As I just mentioned, performing code changes to the TCP/IP Stack's native files is a NO NO. As we have just seen, the flow of the stack has been well thought out for us. If a Stack feature or function can't be controlled by editing the HardwareProfile.h or TCPIPConfig.h file, you don't need to control it.

I like to keep things as simple as possible. I also like to include things in my designs that I've seen work well in other places. If you've ever done anything with a PIC development tool, it's almost a given that you've seen the LCD posing under the White Lightning Photographic Flash Units in **Photo 5**. The Lumex LCM-S01602DTR/M you see there is the LCD of choice for the Explorer 16 Development Board. Now, it's the LCD of choice for our ZeroG - PIC24FJ128GA006 Trainer.

Well, what the heck are we waiting for? Let's wire it up! We already have the PIC24FJ128GA006 LCD I/O pin layout and the LCM-S01602DTR/M adheres to the industry standard LCD pinout. If you're LCD challenged, you can use **Schematic 3** as your LCD integration guide.

MAGIC SMOKE RETENTION TEST

As you can see in **Photo 5**, I've wired in the LCM-

■ **PHOTO 4.** I don't keep many leaded passive components in the EDTP shop anymore. So, I used 0.1 µF @ 16WV 0805 SMT capacitors which are mounted in a point-to-point fashion on the unplated side of the prototyping board.

NUTS AND VOLTS TCPStack v5.20

New IP Address: 169.254.1.1
Connected!

New IP Address: 192.168.1.100

■ **SCREENSHOT 1.** This message was sent from our ST3232 RS-232 port which is set by the stack for 19200 bps, eight data bits, no parity, and one stop bit. Both the LED and TeraTerm Pro messages are generated by the Stack's Announce module, whose functionality is contained within the Stack's Announce.c file.

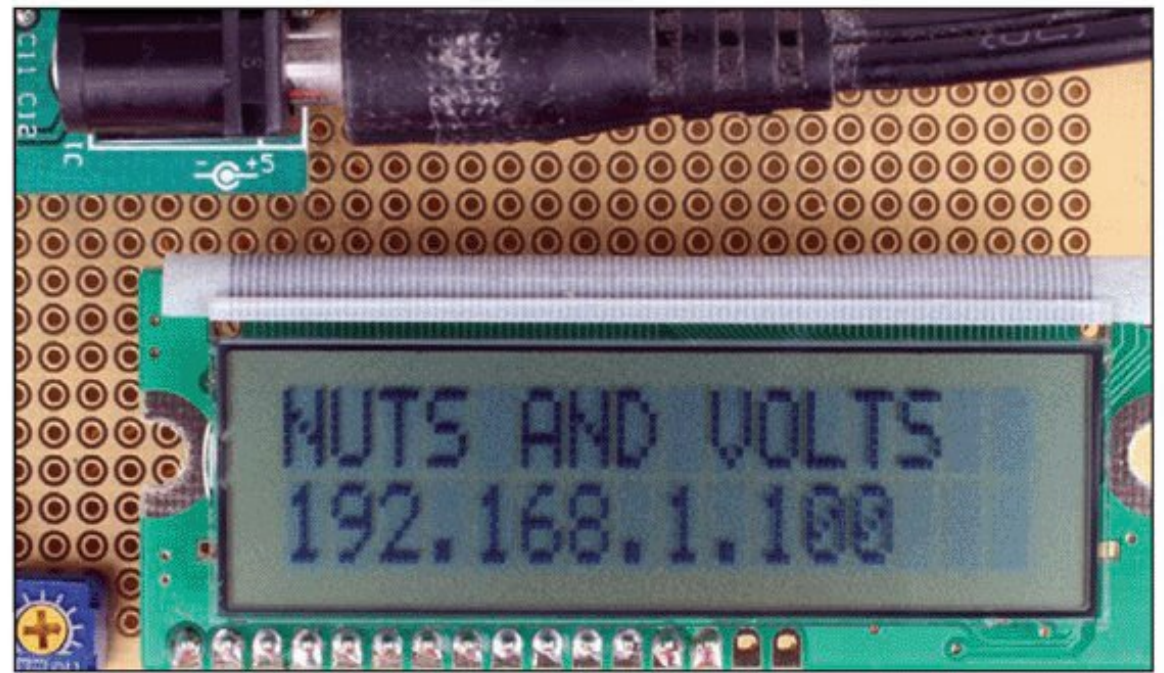
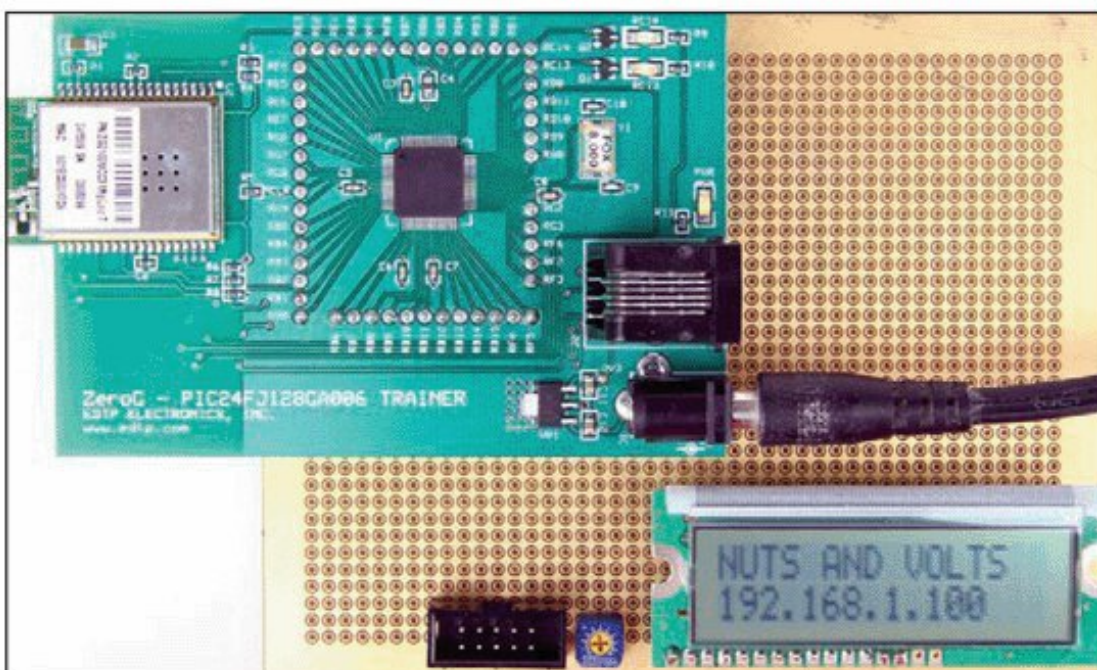
S01602DTR/M LCD module to keep our new RS-232 interface company. The LCM-S01602DTR/M LCD module is a five-volt device. That won't present any problems for the PIC24FJ128GA006 as this LCD module's digital inputs will see the PIC24FJ128GA006's signals as valid TTL levels.

It appears everything is working as designed. When our newly updated Trainer is powered up, we are immediately presented with a banner message and default IP address in the LCD pixels. In our case, the IP address shown is a DHCP-assigned IP address that was leased to the ZeroG - PIC24FJ128GA006 Trainer by the EDTP shop network. The serial port reported the connection in **Screenshot 1**. The text displayed by the serial port and LCD can be altered in the application file which is called MainDemo.c:

```
#if defined(USE_LCD)
// Initialize and display the stack version
// on the LCD
LCDInit();
DelayMs(100);
strcpypgm2ram((char*)LCDText, "NUTS AND VOLTS "
               "TCPStack " VERSION " ");
LCDUpdate();

#if defined( STACK_USE_UART )
putsUART((ROM char*)" \r\n\r\n");
putsUART( (char *)LCDText );
putsUART((ROM char*)" \r\n");
#endif
#endif
```

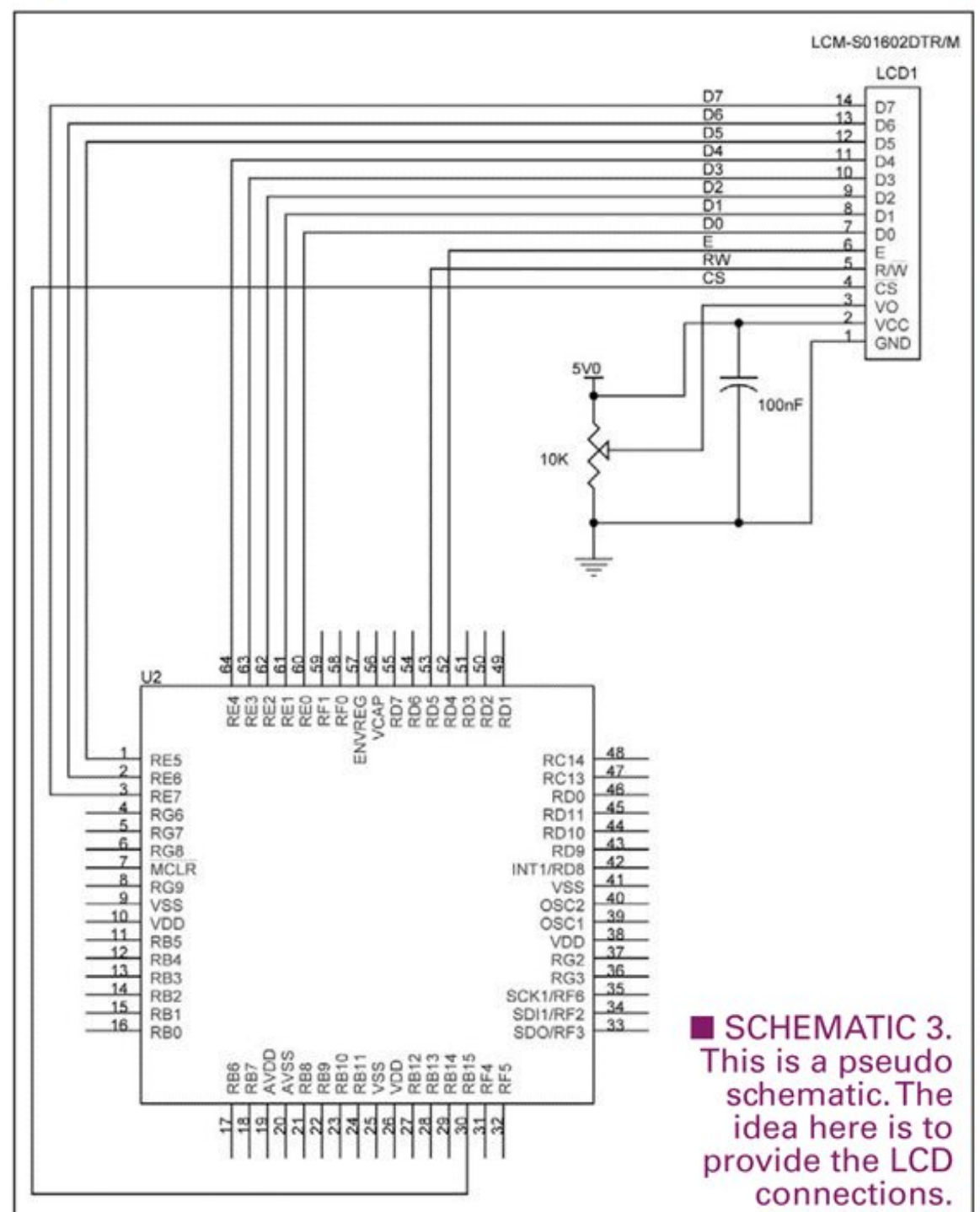
■ **PHOTO 6.** Up and operational under the camera.



■ **PHOTO 5.** I've let the cat out of the bag in this shot. These Lumex LCDs are inexpensive and easily obtained from Mouser and Digi-Key.

You now possess a commanding knowledge of the TCP/IP Stack and the hardware it supports. You're ready to pull some of that potential I talked about earlier into your own 16-bit projects. I'm going to share this knowledge that comprises **Photo 6** with the folks over at *SERVO* in their native tongue. So, post the TCP/IP Stack and the PIC24FJ128GA006 in your Design Cycle cache and hop over to *SERVO* and see how we're going to modify this technology for robotic control purposes. **NV**

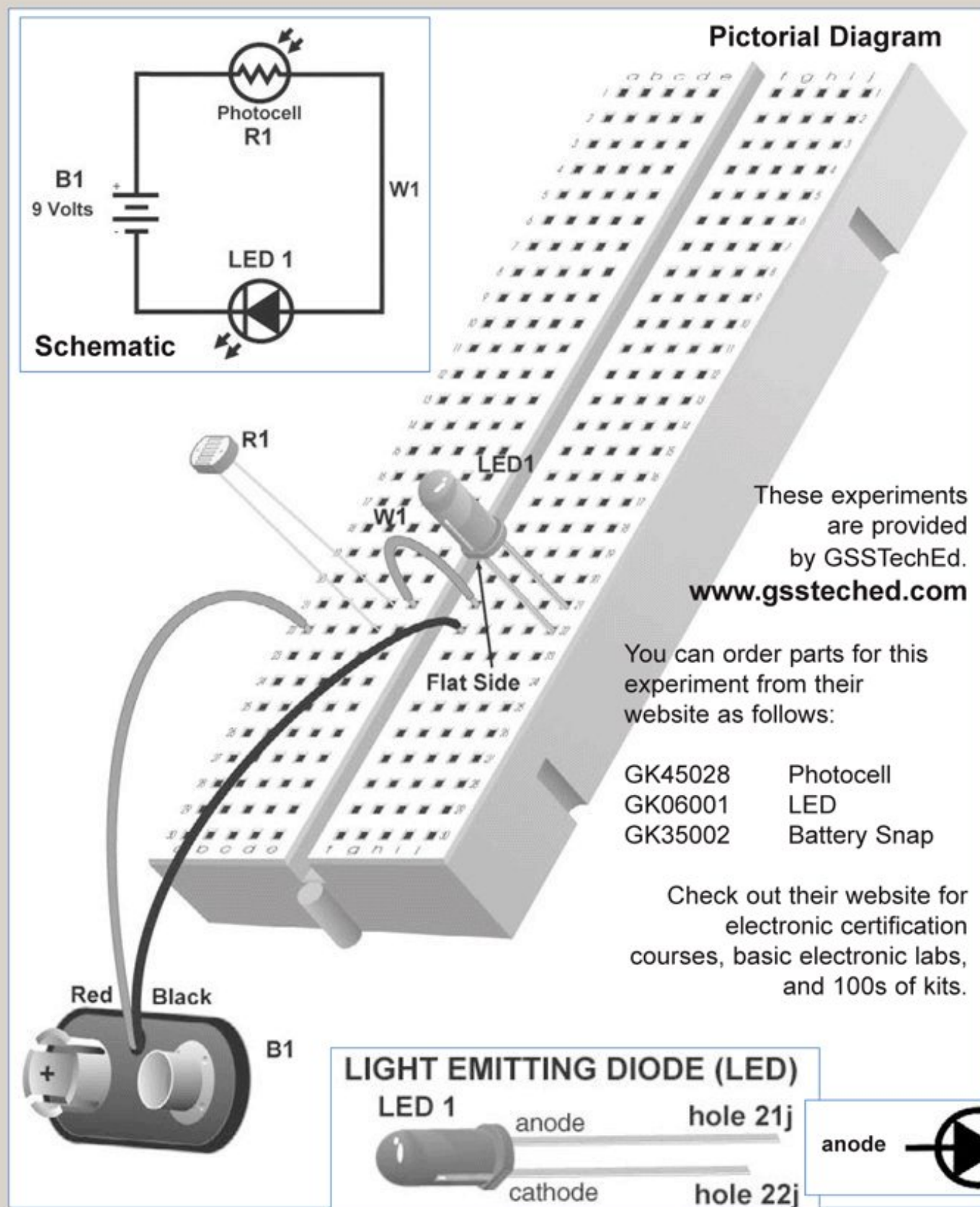
Fred Eady can be contacted via email at fred@edtp.com.



■ **SCHEMATIC 3.** This is a pseudo schematic. The idea here is to provide the LCD connections.

FUNDAMENTALS FOR THE BEGINNER

WHAT A PHOTOCELL DOES



Photocells are used to vary the amount of resistance in many types of electronic devices. For example, they are used to automatically turn on lights when it gets dark. By doing this experiment, you'll see that the photocell varies the brightness of the LED, depending on how much light is hitting its surface.

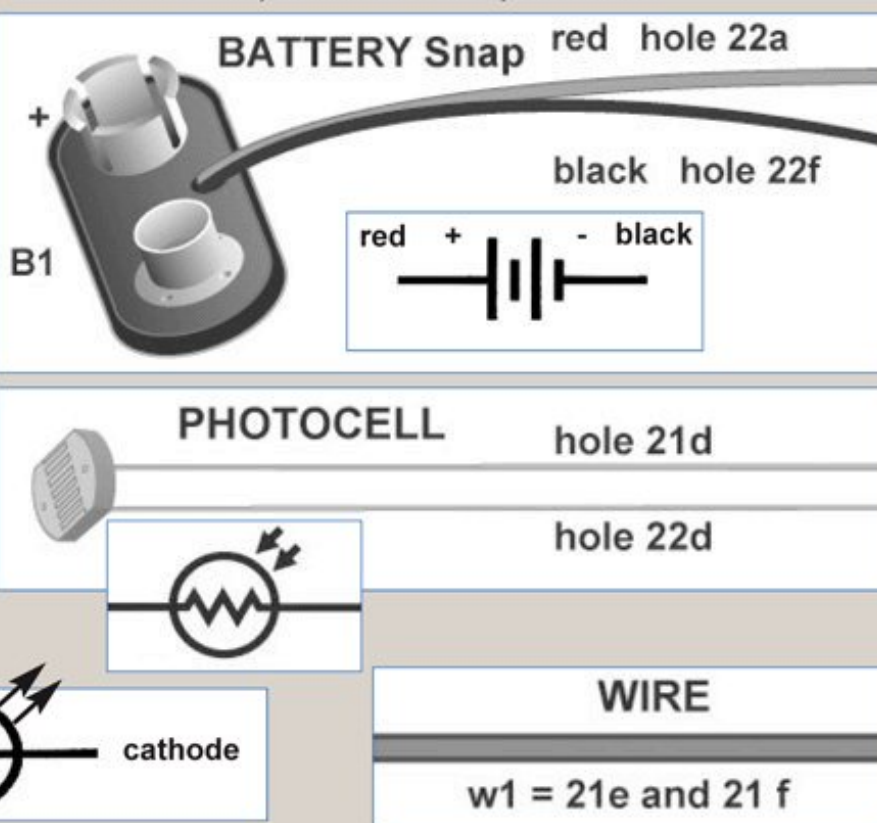
1. Build the Circuit.

Using the schematic along with the pictorial diagram, place the components on a solderless breadboard as shown. Verify that your wiring is correct.

2. Do the Experiment.

Theory: In this circuit, the electronics flow from the negative side of the battery through the LED, through the photocell, and back to the positive side of the battery. The more light hitting the photocell, the brighter the LED.

Procedure: Connect a nine-volt battery to the battery snap and observe the brightness of the LED. Now, cover the photocell with your finger to keep light from getting to it. Notice that the LED gets dimmer when you cover the photocell.



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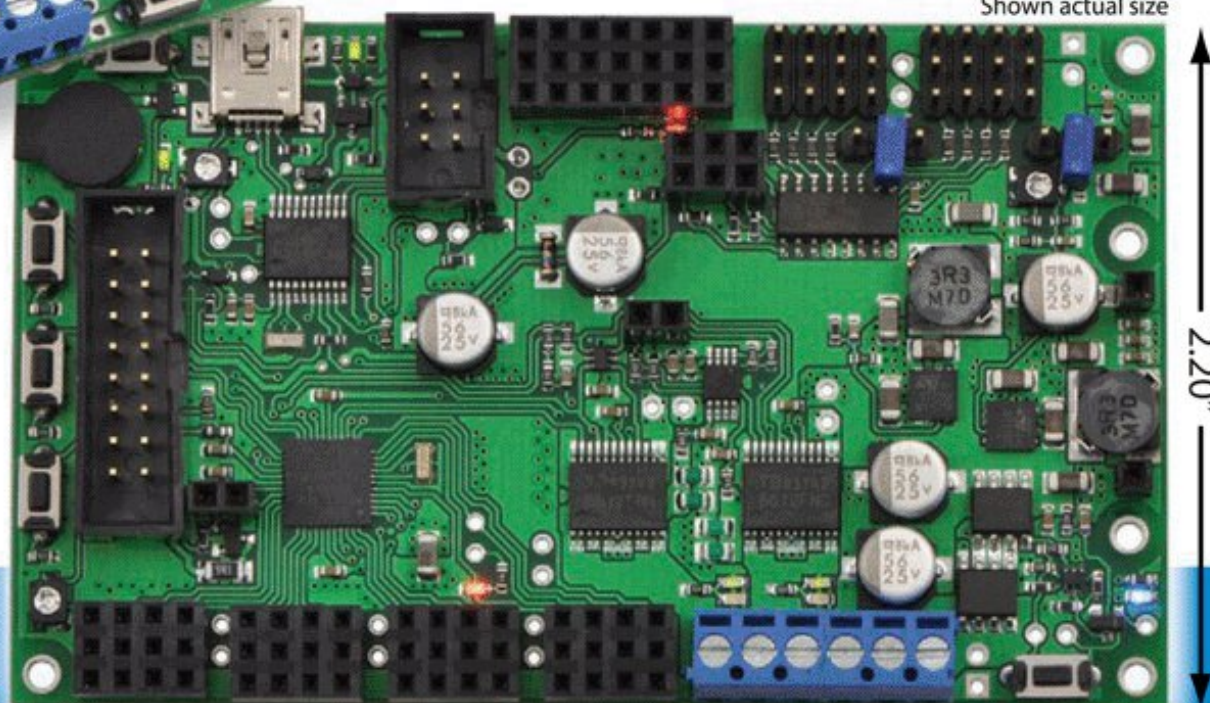
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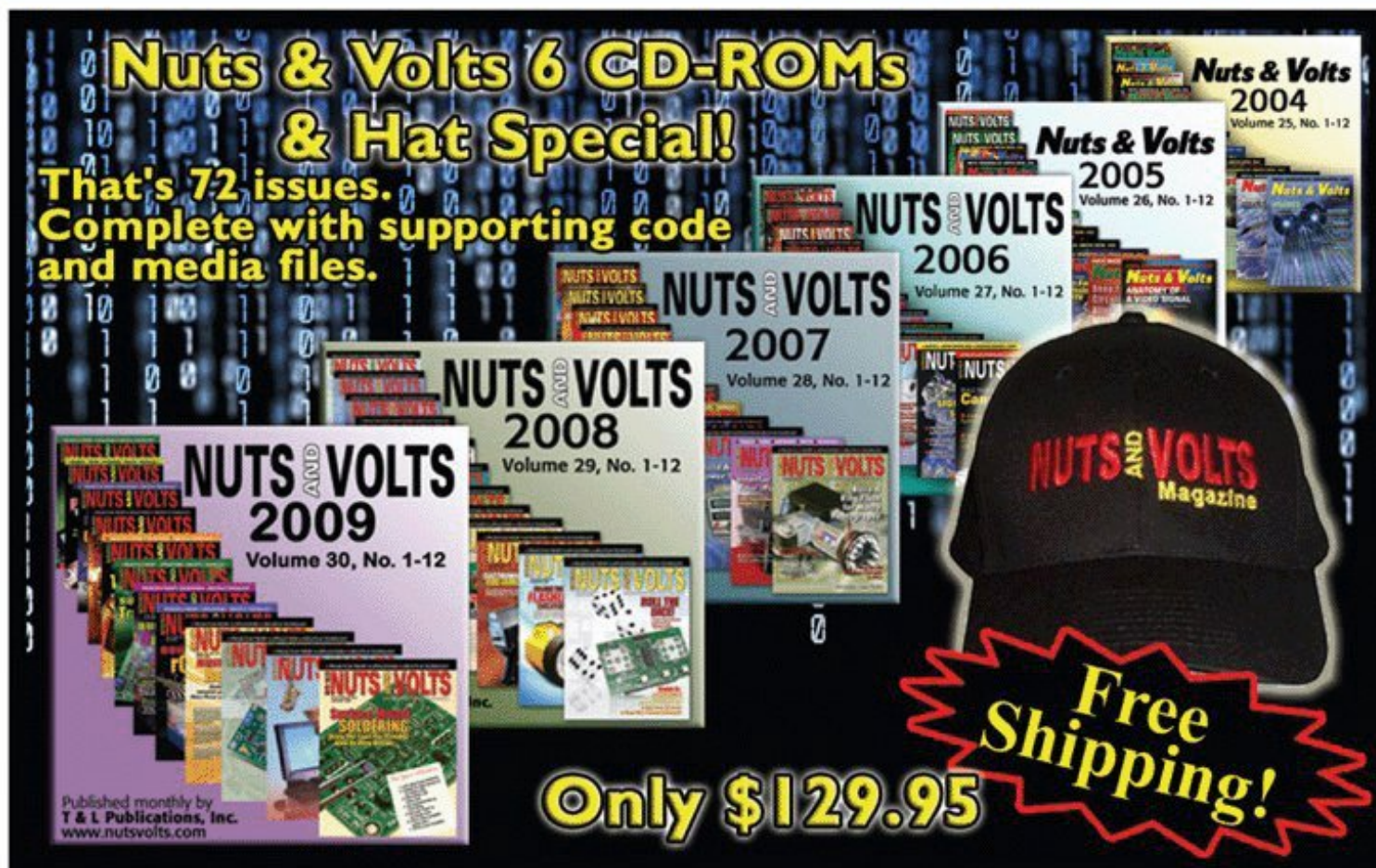
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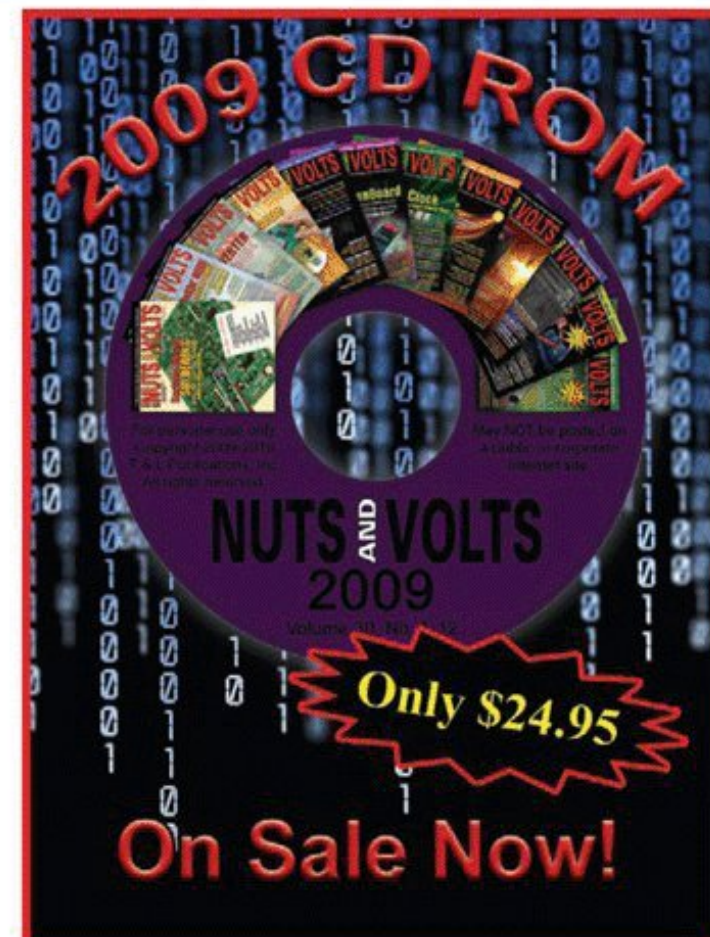


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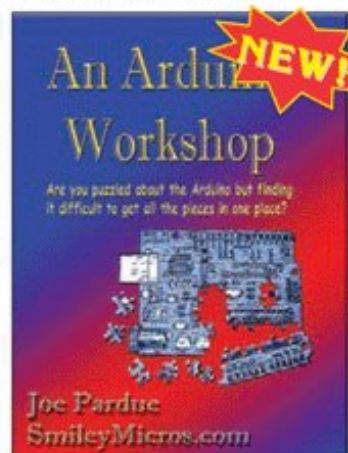
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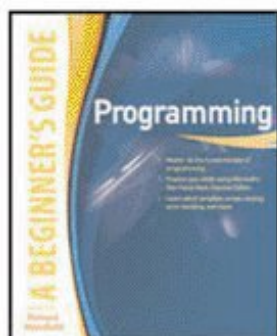
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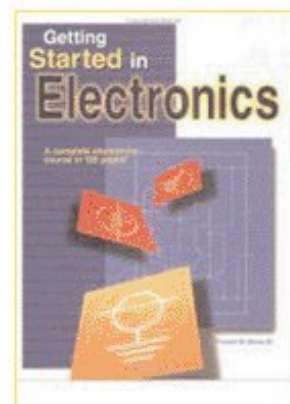
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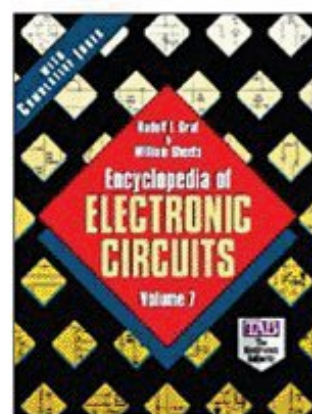
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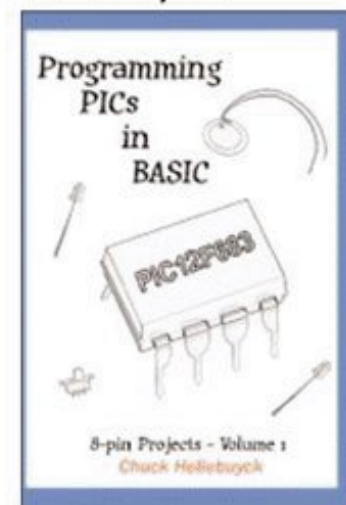
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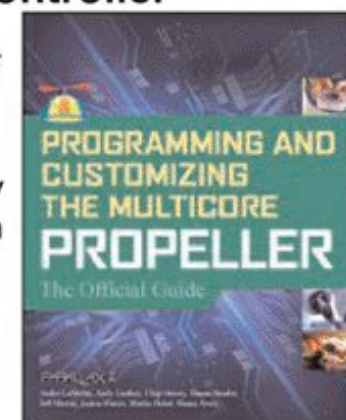
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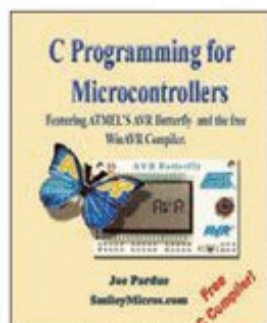
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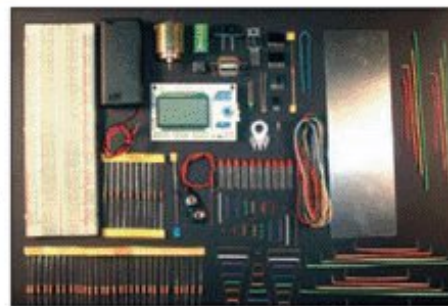
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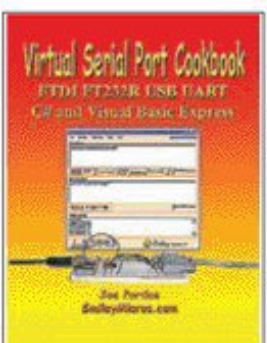
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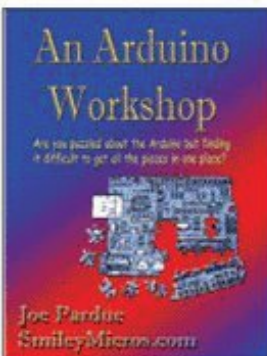
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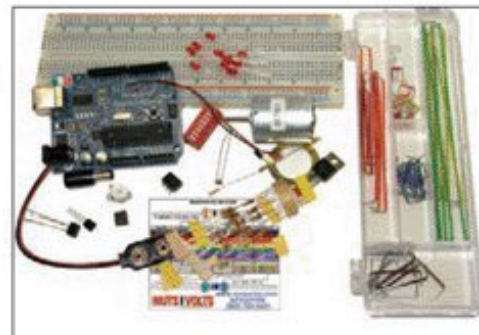
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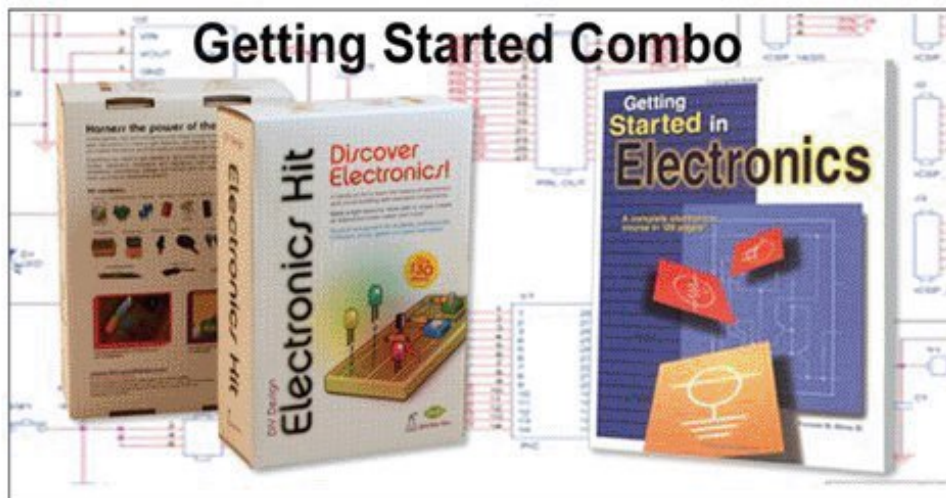


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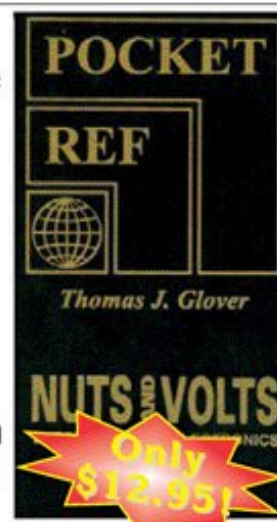
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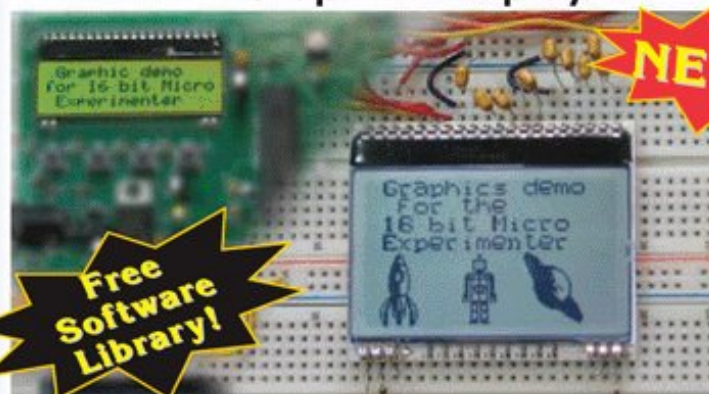
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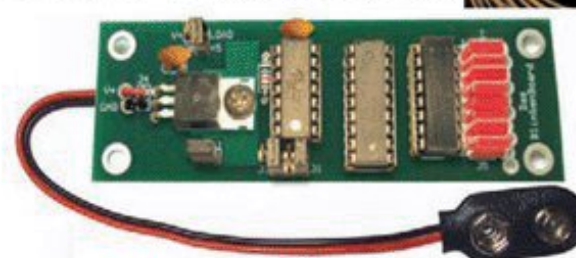
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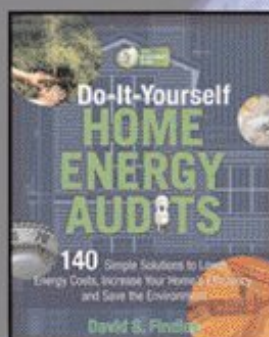
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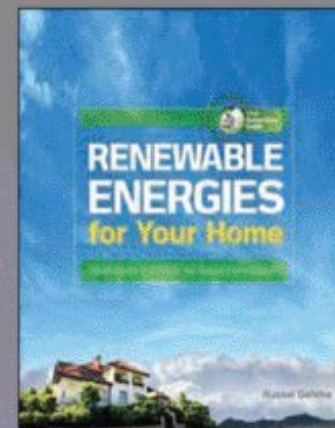
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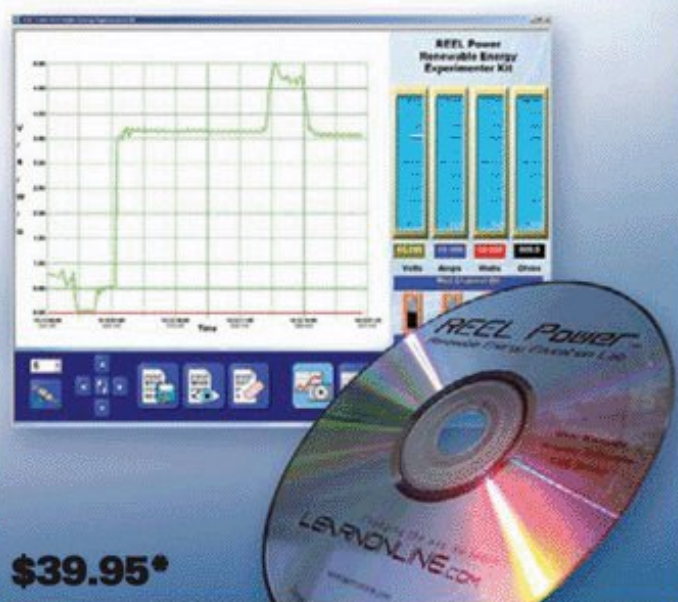


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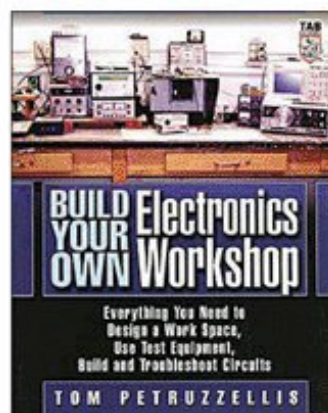
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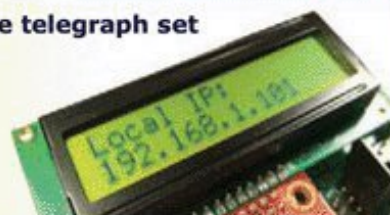
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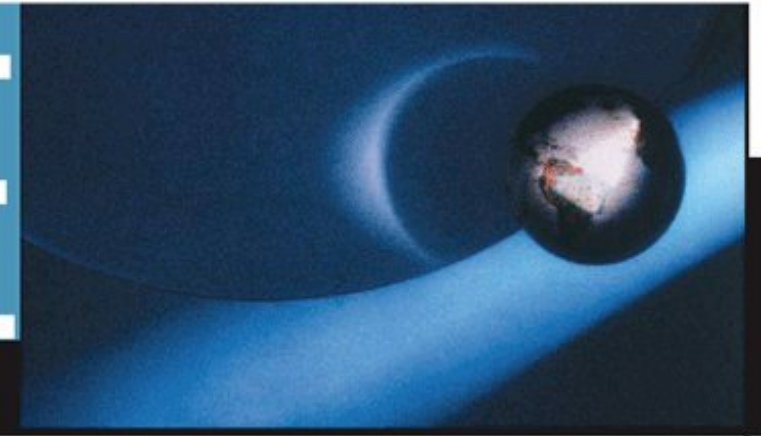
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■ BY L. PAUL VERHAGE

TESTING THE COMPLETE NEARSYS SUN SENSOR

Last time, this column described the construction of a Sun Sensor — a device that gives the near spacecraft the ability to determine the sun's position relative to onboard experiments using cameras. This month, we'll wrap up with my concept test of the sun sensor. Then, I'll add some comments about the new ultraviolet source I installed into my environmental test chamber.

The sun sensor described last time determines the solar quadrant by reporting which photocell has the highest voltage reading. I wondered though, what is the possibility that the sun sensor could report the sun's position within the solar quadrant? If possible, the sensor could report the sun's position much more accurately.

The code used in this test digitized the voltage from a single photocell every five seconds using the READADC command. The reading was then displayed on a laptop with the DEBUG command. Using a protractor, I rotated the sun sensor (in relationship to the sun) in ten-degree increments and recorded the ADC value each time. The test ran twice; the first time without a ping pong ball diffuser over the photocell and a second time with it in place. The ADC readings and the sun angles were then loaded into a spreadsheet. In a third column, I calculated the sun's intensity on the photocell assuming it would be proportional to the cosine of the angle between the photocell's normal reading and the sun. I then created two charts to display the results you see here.

My conclusion from these two charts is that the photocell's small magnitude of voltage change makes it too difficult to determine the sun's position with respect

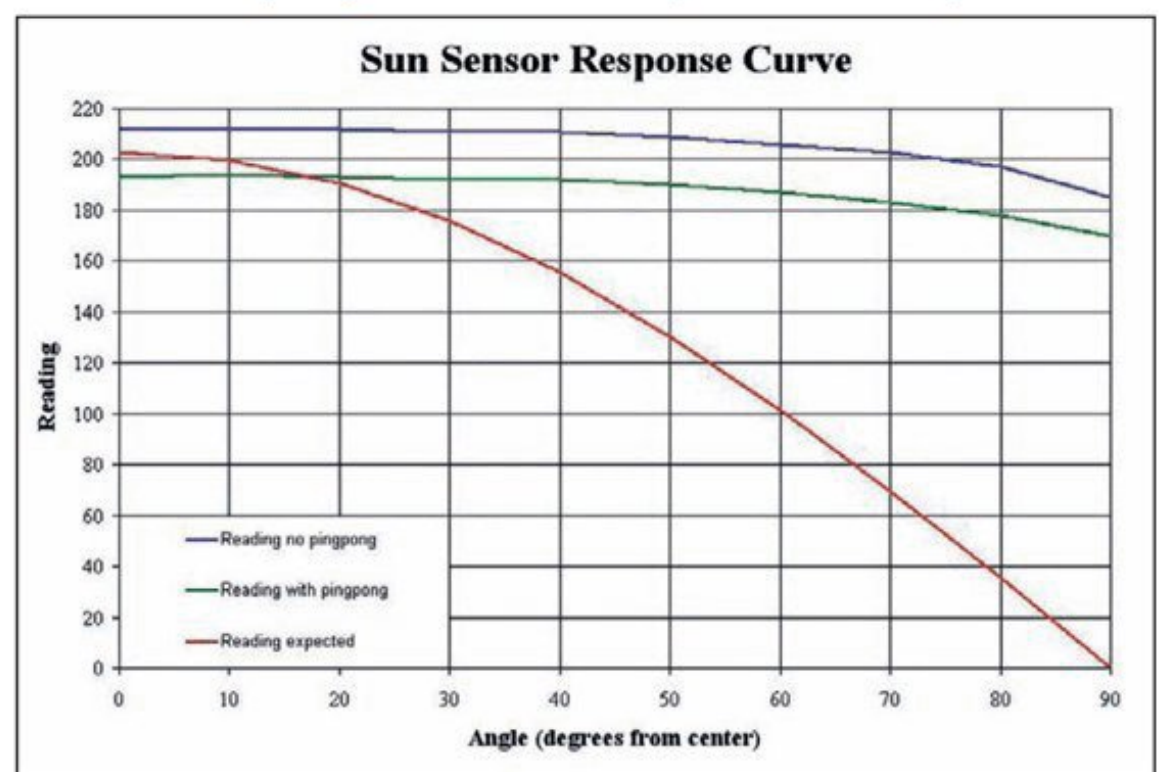
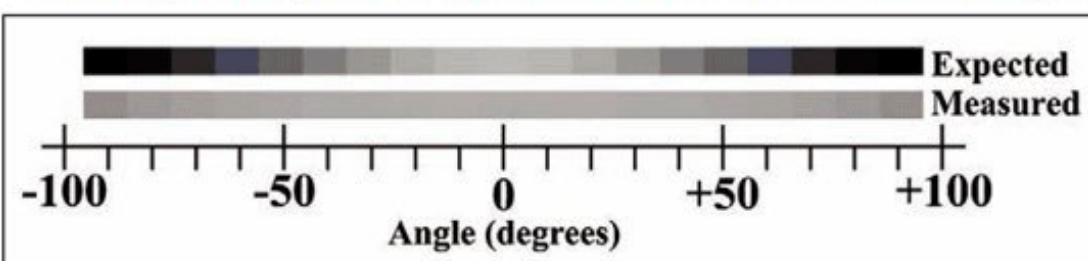
to a single photocell. However, we can probably determine the sun's position within an octant (45 degrees) by sorting the voltages of the photocells. The sun's position would be located between the two brightest quadrants. That is, as long as the voltage of the third highest quadrant is significantly lower than the second quadrant. If the second and third highest photocell values are similar, then the sun is located squarely with the quadrant of the highest voltage photocell.

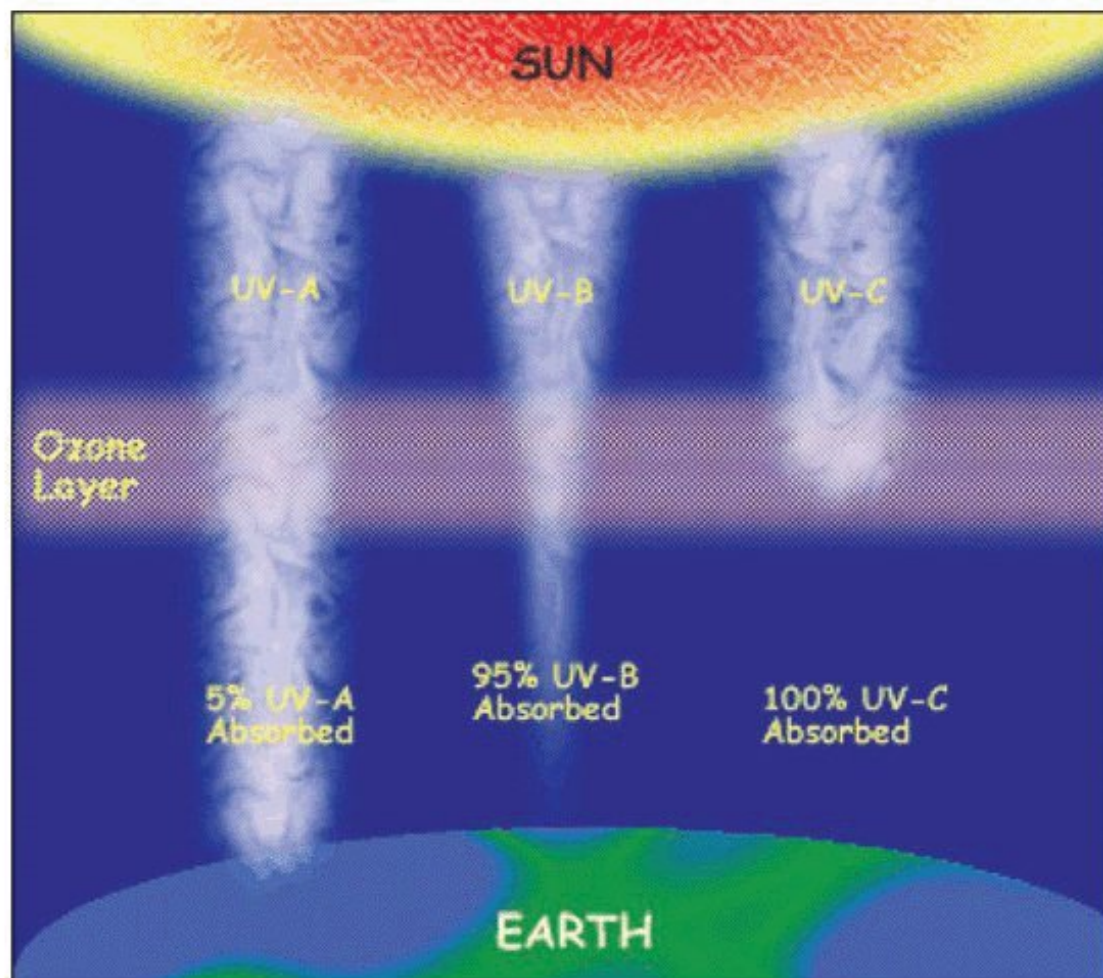
A ROBOTIC APPLICATION FOR THE SUN SENSOR

Not only is the sun sensor useful for near space missions, it's also useful in robotics. A robotic simulator of

■ In this chart, the red curve is the sun's expected intensity over the face of the photocell. It's a cosine function. The other two curves are readings with and without the ping pong ball diffusers in place over the photocells.

■ This is another attempt to graphically represent the response of the Sun Sensor. In this case, the degree of grayness represents the voltage of a photocell. In perfectly black skies, no light shines on a photocell turned 90 degrees from the sun; the voltage would be zero volts (perfect black in this graph). However, according to the results, the blue sky 90 degrees away from the sun still remains bright.





■ A near space flight can climb to over 30 km, so it can experience a significant increase in UV-B but still not receive much UV-A. This graphic is from the Geophysical Institute at the University of Alaska, Fairbanks.

a lunar or Martian rover can use a sun sensor to determine directions in lieu of a compass (this is an issue for these two locations since neither the moon or Mars have global magnetic fields). A robot can also use a sun sensor to determine when the sun has risen or set — very important to a solar powered rover. If calibrated properly, a robotic rover might also use the sun sensor to determine the intensity of the sunlight. If you plan to use the sun sensor in robotics, I recommend drilling out the large mounting holes in the PCB (see January's issue). Bolt two-inch long #4-40 machine screws to the PCB so the sun sensor can attach to the robot. Raise the sun sensor on a mast that keeps it above any other structure on the robot (to avoid shadows). (In the near future, I plan to write an article for *SERVO Magazine* about an articulated robot that uses the sun sensor in this way. So keep your eyes open.)

NearSys is in the process of producing a sun sensor kit for those who do not want to make their own PCB or gather the needed components. Go to NearSys.com/catalog for more information.

ADDING UVC TO THE ENVIRONMENTAL TEST CHAMBER

In my Nov '09 column, I discussed how I incorporated ultraviolet into the simulator. However, I'm not totally happy with this UV source (UV LEDs) because its ultraviolet light is too close to the violet part of the visible spectrum. As many *Nuts & Volts* readers know, scientists divide the UV spectrum into three ranges: A, B, and C. Ultraviolet A, or UV-A, spans a wavelength range from 400 to 315 nm — this is the band of UV



■ A \$10 source of hazardous ultraviolet. Just the thing for the near space environmental test chamber on a budget. **Do not look at the UV from these lamps.**

emitted by the affordable UV LEDs in my environmental chamber. Of the remaining two bands, UV-B spans from 315 to 280 nm and UV-C spans from 280 to 100 nm.

UV-A from the sun reaches the surface and is not usually considered very dangerous. However, it can cause indirect damage to our DNA (via the creation of free radicals, or highly reactive molecules). Too much damage can lead to cancers. UV-C is the just the opposite — it's known to be extremely hazardous.

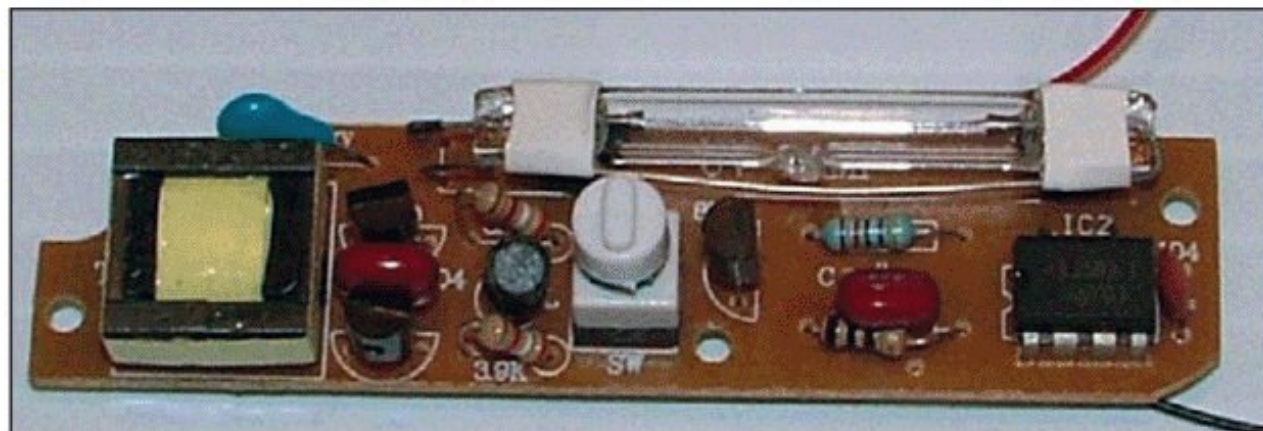
Fortunately, it's blocked high in the stratosphere. Ozone in the stratosphere strongly attenuates UV-B, but some still reaches the surface. The small amount that does make it to the ground promotes the healthy production of vitamin D and is responsible for the sunburns we get each summer.

To improve the quality of my near space simulator, it needs to have a source of UV-B. LEDs capable of emitting this frequency are commercially available, but are too costly at this time. UV-C, however, is used as a germicide and is readily available in items like water purifiers for backyard ponds. Since I can't get an inexpensive source of UV-B yet, I decided I'd settle for mixing some UV-A and UV-C (am I right in thinking that mixing UV-A and UV-C averages out to UV-B?). Actually, I initially thought I had found a good UV-B source when I ran across the UV source described this month. It wasn't until after I had installed the lamps into my environmental chamber that I discovered they were really UV-C. Therefore, here's my experience with adding another ultraviolet source to my environmental test chamber. Readers may find other uses for this inexpensive UV-C source.

The DenTek toothbrush sanitizer is a plastic case containing batteries, an ultraviolet lamp, drive circuit, and power switch. The drive circuit boosts the voltage of its two AAA batteries to the 470 volts peak-to-peak it takes to operate the UV lamp (which is an uncoated mercury vapor lamp). So, let's violate another warranty by bashing this commercially available product into something more useful.

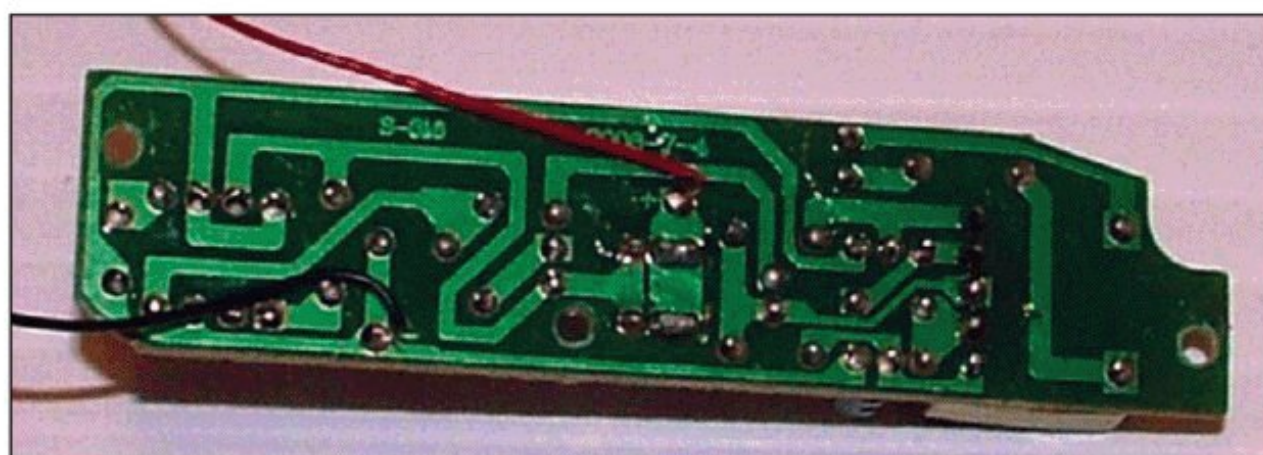
To gain control of the UV lamp, you have to open the

■ The top of the lamp driver printed circuit board. The eight-pin IC produces a sine wave at 44.4 kHz to drive a small transformer that produces the 470 Vpp needed to power the tiny mercury lamp.



case by removing three screws from the back and pop the case open. Once opened, take out the three screws holding the PCB to the case. Once free, the printed circuit board looks like what you see in the photos.

There's no ON-OFF switch on the DenTek toothbrush sanitizer. Instead, there's a momentary pushbutton switch that's activated by a small tooth in the lid of the case. There are six contacts on the switch with three on each side of it. The switch leads are soldered to two PCB copper pads (two leads on the first pad and the other four on the second pad). The red wire (+3V) must be moved to the other pad to electrically bypass the switch. The photo shows the PCB pads I'm talking about.



■ On the bottom of the printed circuit board, you'll find the power wires. You can't miss which wire is positive and which is ground since they're properly color coded and the PCB is labeled.

I spliced a two-cell AAA battery pack to the PCB's red and black wires. I chose not to incorporate a switch since I'll be the only person turning the UV lamp on and off. This means to power the UV lamp on and off, I either put the batteries into their holder or remove them. You may opt to add a switch. In that case, you can either solder a toggle switch between the battery holder and the PCB or use a AAA cell holder with built-in switch.

Avoid exposure to the UV lamp. When energized, the lamp produces UV-C at a wavelength of 254 nm, which is harmful to DNA in cells (this includes bacteria, fungi, and viruses). The direct damage from UV-C occurs when UV photons convert the hydrogen bonds (weak bonds formed by electrostatic attraction) between some nucleotides in a DNA strand into covalent bonds (stronger bonds where electrons are shared between atoms). Since the covalent bond is stronger, the DNA is unable to unzip itself for gene expression and DNA replication. Basically, covalent bonds foul the operation of the DNA machine and so the cell dies.

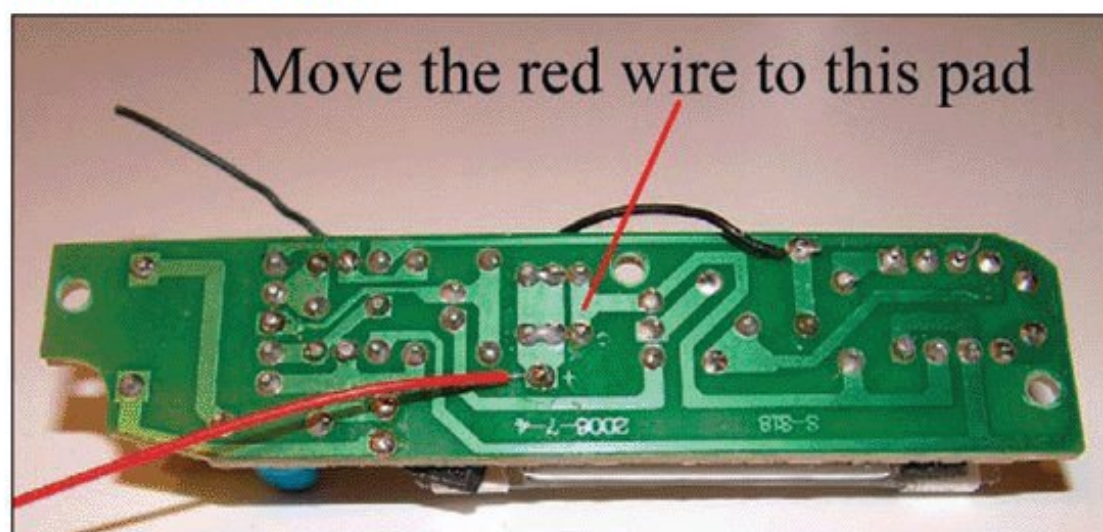
I mounted two UV-C lamp circuits alongside the LED UV-A bank inside my near space environmental chamber. The new and improved UV bank sits at the top of the

chamber where it shines light on the victim below. Experiments inside the chamber get exposed to intense cold, bright UV, increased ionizing radiation, and a vacuum (which feels like home in near space). In future experiments, I'll expose cell cultures to these conditions to see which can still multiply afterwards. Experiments like this can identify microorganisms that could potentially survive a trip from Earth to Mars after being blasted off the Earth by a meteorite impact.

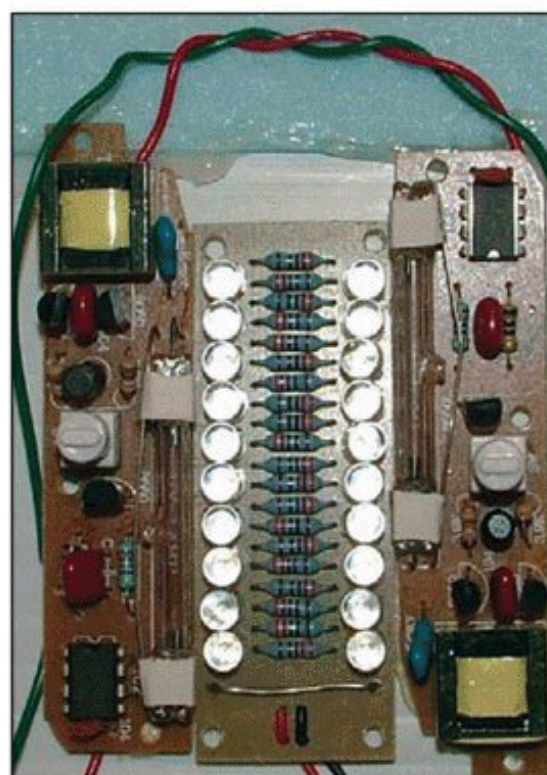
The next stage for the near space environmental chamber is to find a better radiation source (that includes adding betas and gammas) and an affordable UV-B source. Once I locate these, you can count on me to write about it in *N&V*.

Onwards and Upwards,
Your near space guide **NV**

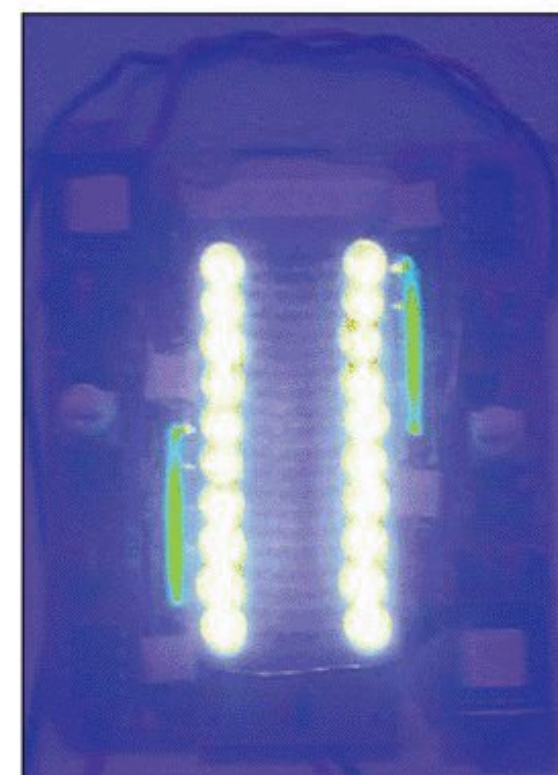
■ Melt the solder holding the red wire to its current pad and pull it free. Then, place the wire in contact with one of the two solder pads on the other side of the switch and solder it back down.



■ With the lamps off, this UV bank looks harmless.



■ But apply power and it's a DNA nightmare. Apparently, my digital camera has a problem adjusting exposure time and focus in UV light.





#22 SMILEY'S WORKSHOP

C PROGRAMMING - HARDWARE - PROJECTS

Busy As A BeAVR

by Joe Pardue

Follow along with this series! Joe's book & kits are available at www.nutsvolts.com

Recap

Last month, we finished busting up the Arduino and began reassembling the resulting ruins as the BreadboArduino. We learned to use it with the regular free Atmel tools AVRStudio/WinAVR and a helper tool that I provided: AVRUP to ease the use of AVRDude. Now we can move on to more capable software and hardware (okay, IMHO) without forever trying to explain the word Arduino. Keep in mind that I love the Arduino for beginners, and wrote the book, *An Arduino Workshop* that along with the Arduino Projects Kit (both available from *Nuts & Volts*) are, in my totally unbiased opinion, the absolute all-time best possible starting point for beginners. But enough of my public display of humility. This month, I introduce the BeAVR (Breadboard enabled AVR). The hardware version shown in **Figure 1** looks suspiciously like the BreadboArduino on steroids. That's because the BreadboArduino uses the 28-pin ATmega328 and the BeAVR uses the 40-pin ATmega644. That's twice the memory and 12 more I/O pins! You can't be too rich, too thin, have too much memory, or too many I/O pins. And, yes, we are going to be as busy as a BeAVR.

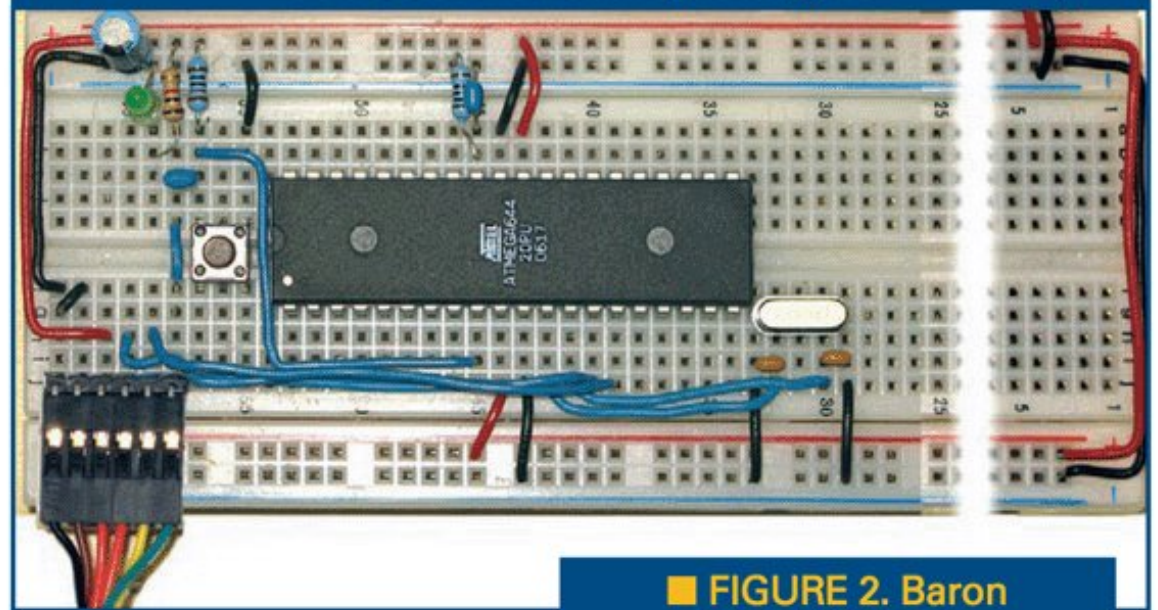
So Why a BeAVR?

BeAVR is an open source design concept for AVR hardware and software. The hardware schematics can be implemented on a breadboard (as we will see first) or on a PCB which we will introduce next month. We've seen most of the software in earlier workshops; the main addition will be to use a bootloader for the ATmega644. So, what's a bootloader?

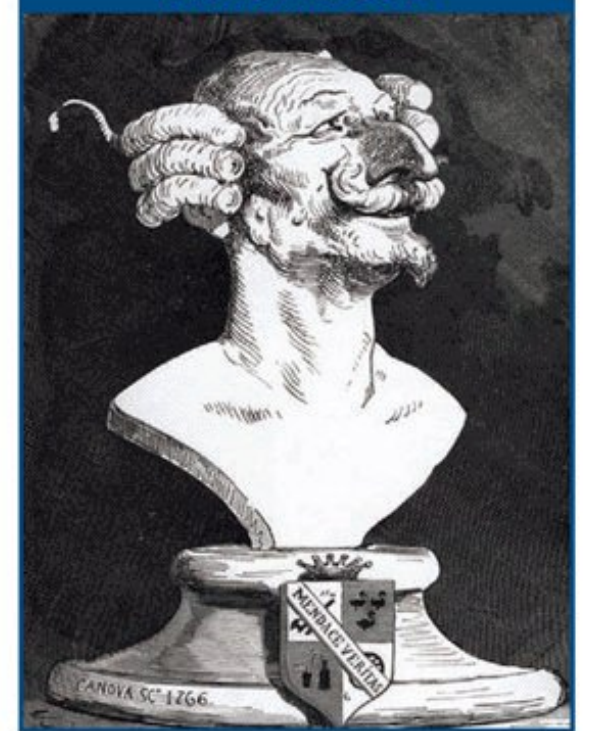
Baron Munchhausen and the Bootloader

In the early part of the 18th century, the exact date is unknown; Baron Munchhausen saved himself from drowning in a shipwreck by pulling himself out of the sea by his own bootstraps. A particularly miraculous feat since (as you may have noticed from his bust shown in **Figure 2**) he had no arms. In homage to this great man, computer folks have used the term 'bootstrapping' to mean the emergence of a complex system by starting with simple components and progressively developing greater complexity on top of them. In our case, a bootstrapper (a.k.a., bootloader)

■ FIGURE 1. BeAVR prototype.



■ FIGURE 2. Baron Munchhausen.



is a small simple program that can be used to load and run a large complex program.

I like to brag about how many years ago, I wrote an 81 byte machine code bootstrap program for the 8051 that I input by hand (my hand, to be exact) using DIP switches into an SRAM chip powered by a lantern battery. Note that SRAM is volatile memory and forgets everything the moment power is removed. This tiny program allowed me to download a hex file to the 8051 from an original IBM PC over an RS-232 connection. I learned a lot — mainly how difficult it was to input a lousy 81 bytes using DIP switches — and I tended to do things the hard way for some (yet to be explained) reason. I also invented several new words when I knocked the alligator clips off the battery in the midst of one of my test runs causing the SRAM to immediately forget everything I'd told it. After finding where I had thrown all the pieces, I joined the rest of the world and started using non-volatile memory in the form of an EPROM (Erasable Programmable Read Only Memory) which has memory that will remember what you told it if the power has been removed. The EPROMs I used were kind-of cool because the IC had a transparent window in the top showing you the silicon chip memory inside. This wasn't for your personal voyeuristic entertainment though. It was so you

could shine a UV lamp onto the memory and erase it.

This operation took a while, the software test procedure generally went like this: fail, pull out the EPROM, stick it in a UV eraser, go get a cup of coffee and watch a soap opera, load the next iteration of the code using an EPROM programmer, fail, pull out the EPROM ... it was actually even more boring that it sounds. Then, some genius figured out a way to erase the EPROM with electricity thereby creating the EEPROM (the additional E stands for Electrical).

EEPROM is a kind of memory that won't go brain dead if you pull the alligator clip off the lantern battery, and you don't need a special eraser to erase it. The next innovation was Flash EEPROM, more commonly known as Flash memory. This memory was much cheaper than regular EEPROM because it erased memory in large blocks rather than a byte at a time. It's the kind of memory you usually find on memory cards and USB Flash drives. This innovation is one of the reasons that we have AVRs. The guys who designed the AVR wanted program memory that could be both non-volatile and easily erasable, so they got with the folks at Atmel (who were making cash on Flash). So, what does this have to do with Baron Munchhausen? Well, the AVR architecture has some special features that allow us to use Flash memory as a bootloader.

All right, that was strange, but the points were: A bootloader allows you to program a microcontroller without an external programmer; and Flash memory is great for a bootloader because it is non-volatile so you can use lantern batteries and alligator clips without cursing and throwing things.

Chicken or Egg

A bootloader is a program that allows you to upload a program without having an external programmer. However, the bootloader *IS* a program, so how do you program it onto a micro? Well, you use an external programmer. But — you ask — if the reason for a bootloader is so you don't need an external programmer ... but you need one to put the bootloader on the micro ... Wait a minute! This is confusing! The answer is that if you have an external programmer, then you don't need a bootloader — but if somebody is kind enough to program the chip with a bootloader for you, then you don't need an external programmer.

Last month, we relied on SparkFun (www.sparkfun.com) to put a bootloader on an ATmega328 for our BreadboArduino. This month, we are going to look at how to put a bootloader on an ATmega644. Atmel has several really good programmers that would fit our needs: the AVRISP mkII; the Dragon; and the STK-500 — in order of cost and capability. Since we will be using ISP (In System Programming), any of the three would suffice. I'll go with the mid-priced (~\$50) option to save space.

Building the BeAVR on a Breadboard

To make this truly open source, I thought it best to

Sch. Part	Description	Mouser Part #
IC1	ATmega644	556-ATMEGA644-20PU
H1	Right Angle Header	517-500-01-36
Sch. Part	Description	SparkFun Part #
Q1	Crystal 16 MHz	COM-00536
S1	Mini Pushbutton	COM-00097
C1,C2	22 pF Capacitor	COM-08571
C3,C4,C5	100 nF Capacitor	COM-08375
R1	10K ohm Resistor	COM-08374
R2,R3,R4	1K ohm Resistor	COM-08980
LED1	Red LED	COM-00533
	Breadboard	PRT-09567
	Hook-up Wire (22AWG)	PRT-08025

Table 1. BeAVR bill of materials.

build this first on a breadboard — which is about as open as you can get — then next month, take the design to a PCB. I had all sorts of fun building the prototype on a breadboard. (And by fun I mean real pain and suffering.) Since this is open source, you too get to share in the fun.

BeAVR Schematic

The BeAVR schematic shown in **Figure 3** is much like the BreadboArduino from last month with the ATmega328 swapped out for an ATmega644.

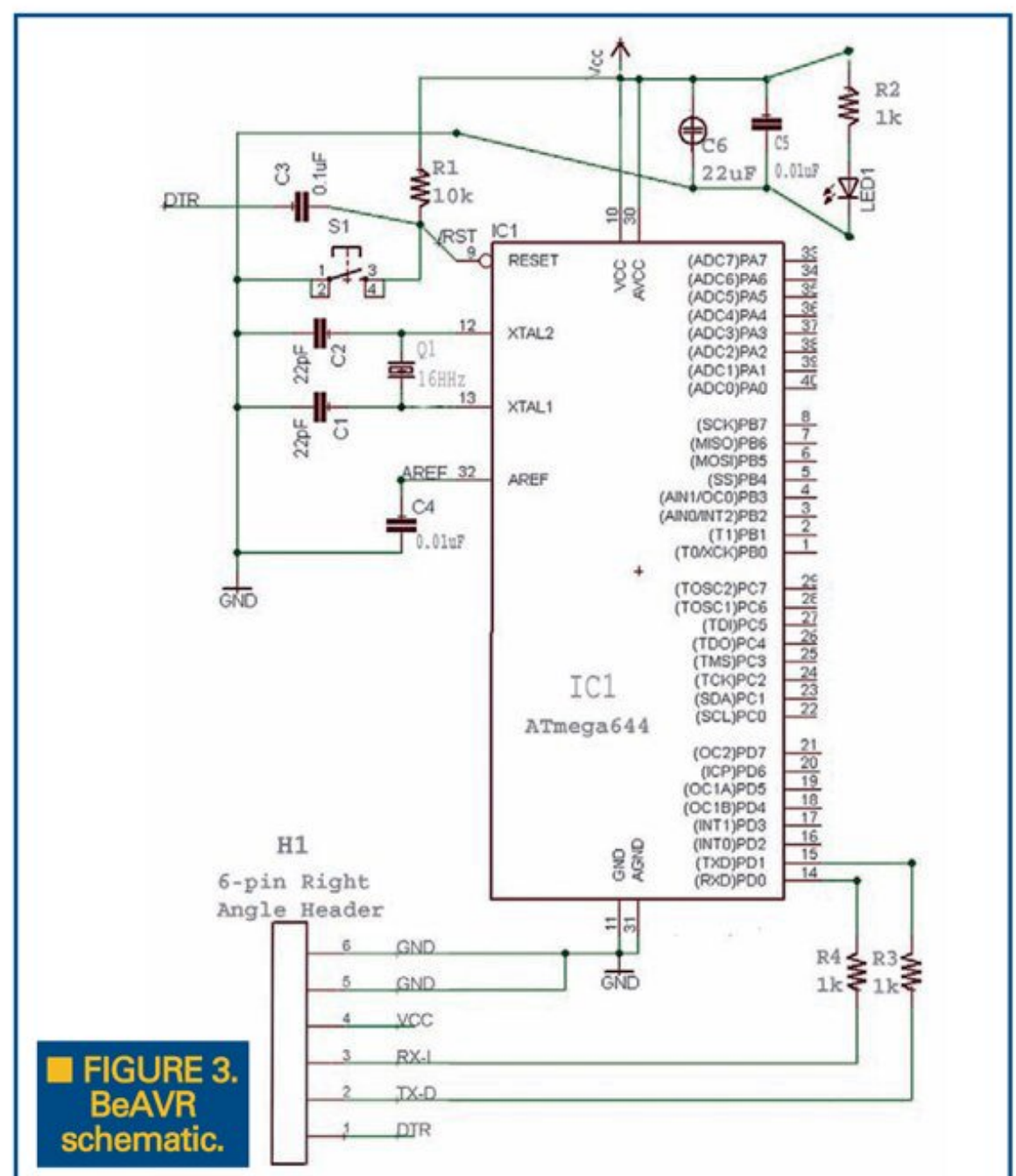
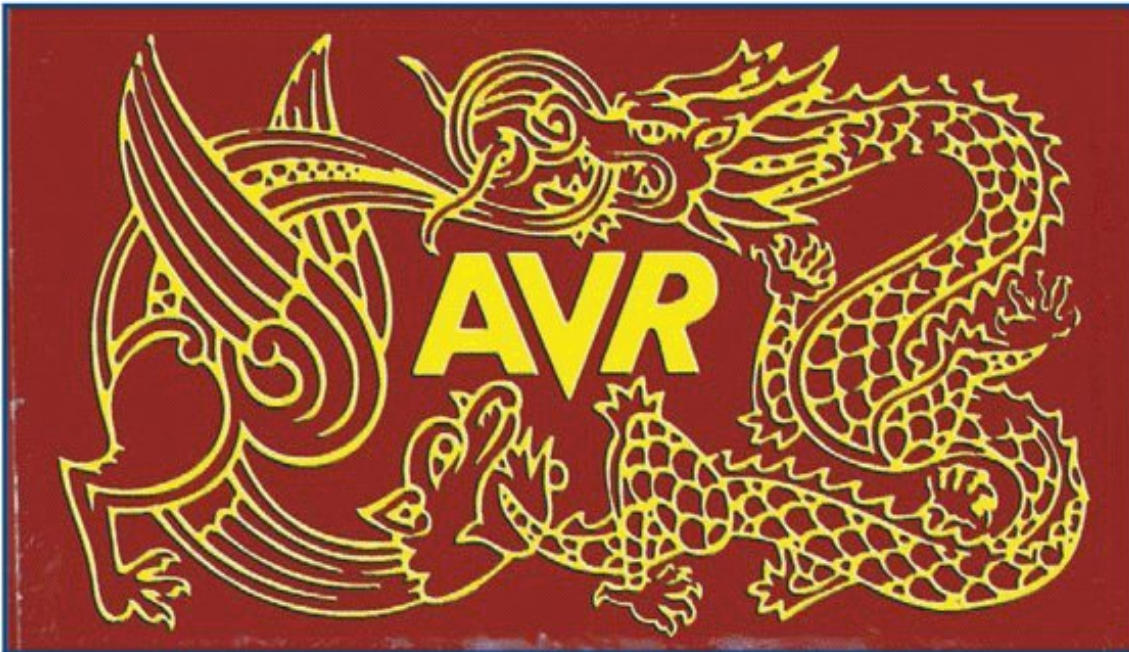


FIGURE 3. BeAVR schematic.



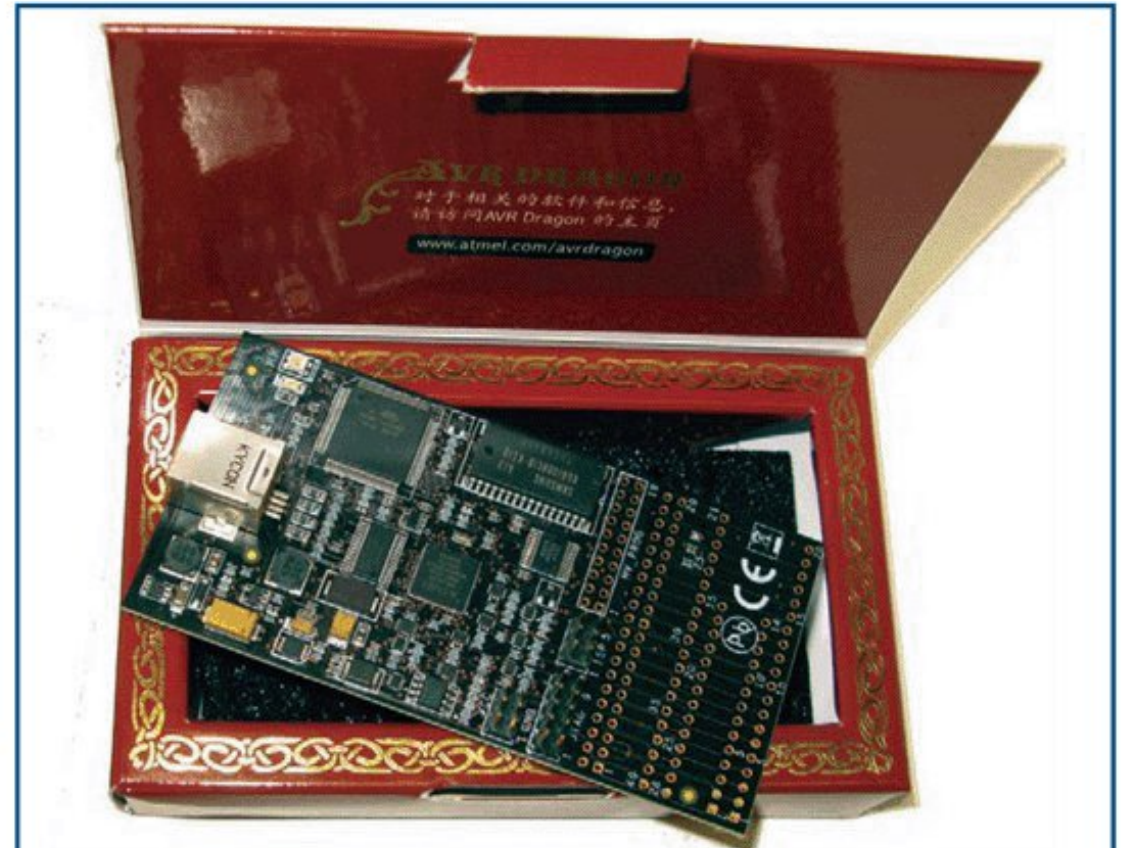
■ FIGURE 4. AVR Dragon box.

Is a Programmer a Person or a Machine?

When I'm sitting at my laptop writing code in either the Arduino IDE or AVRStudio editors, I'm a programmer and I'm programming. After I compile the code and upload it to the AVR, I use a programmer for programming the IC. So, yes, there is a bit of confusion with the words programmer and programming. From one view, it is a human activity and from another it is a machine activity. We will see how to use an Atmel AVR Dragon as our hardware programmer. If you can get your hands on an AVRISP or an STK-500, there is no need to get a Dragon since both will do ISP programming just as well.

AVR Dragon

I've got to admit that the AVR Dragon provides the best out-of-box experience I've ever had with a programmer — mainly because the box is so darn cool (**Figures 4** and **5**). The cover has a Norwegian and a Chinese Dragon biting each other's tail. (There just has to be an interesting story behind that.) Unfortunately, once you get it out of the box, the trouble starts. Don't get me wrong, this is a great little board and very economical, but you've got to do some serious homework to use all its features. Plus, you need to purchase additional parts to make it do anything. Neither the jumpers nor the socket shown in **Figure 6** come with



■ FIGURE 5. AVR Dragon out of the box.

the Dragon. That shouldn't be considered a fault since these items would raise the cost and frankly, anyone using the Dragon should already know how to acquire and use the extras. One warning: Do not touch this board when it is powered. Some earlier Dragons failed when touched, and while the problem is supposed to be fixed, why on earth would you want to touch a powered-up board, anyway? Just keep your hands to yourself mister!

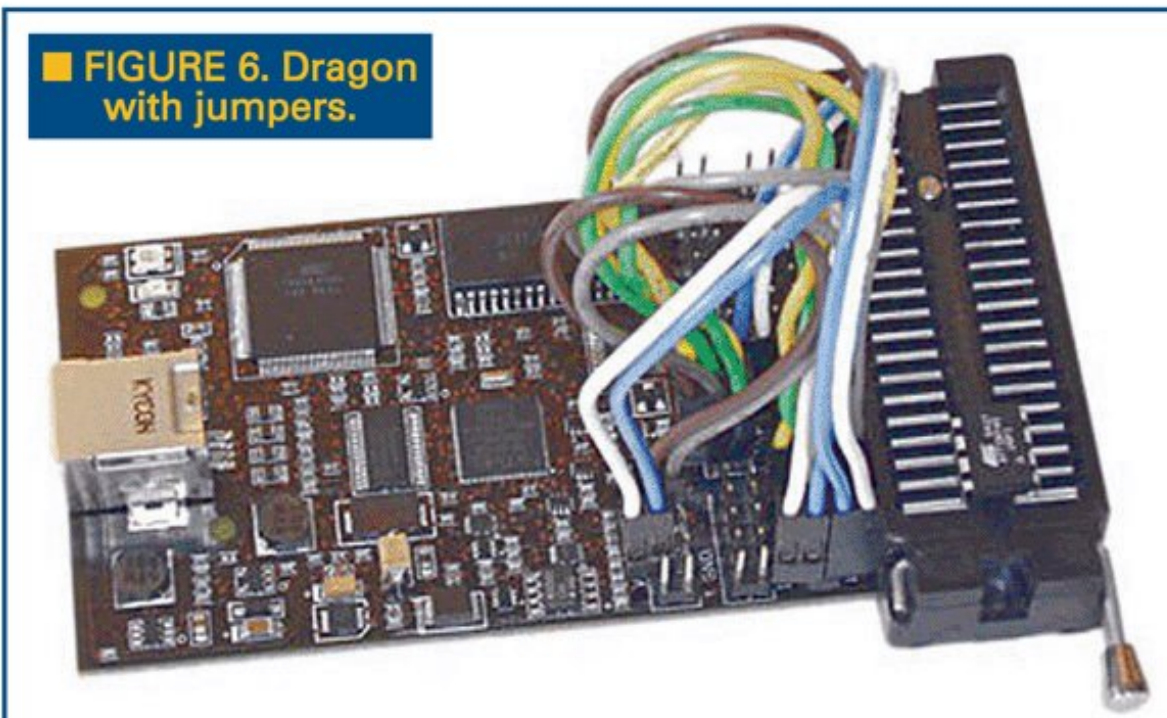
Dragon Rider

Frankly, the Dragon — while economical — is a bear for the novice to set up. You will need various jumper wires, cables, and sockets that don't come with the board. One really good solution to this problem is to get the Dragon Rider kit from www.ecrostech.com as shown in **Figure 7**. This solution more or less turns the Dragon into an STK-500 but with USB and an LCD, so it is well worth considering.

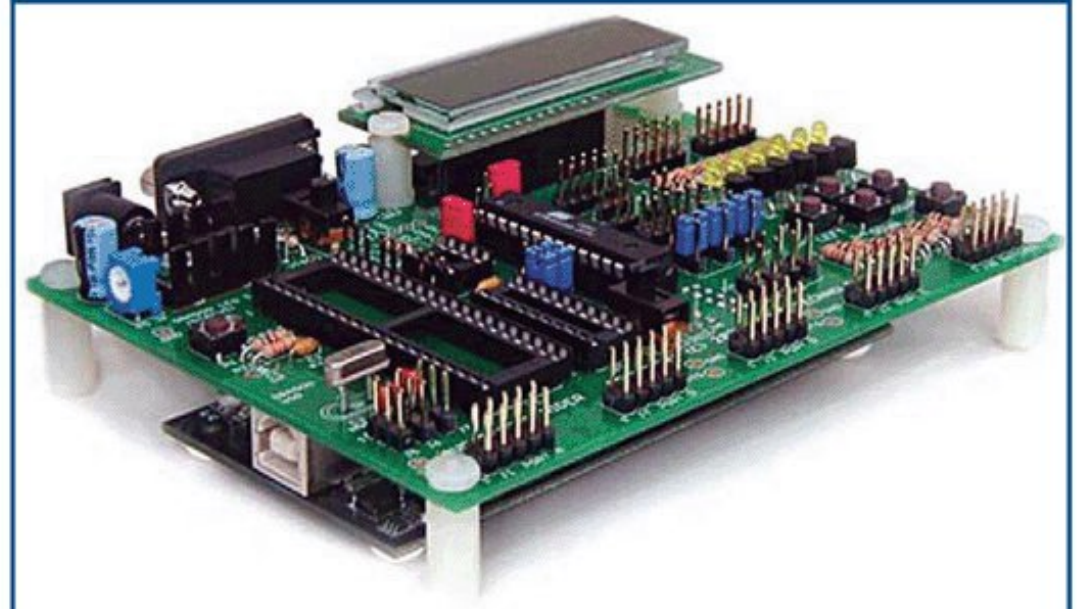
Dragons, Medusas, and BeAVRs?

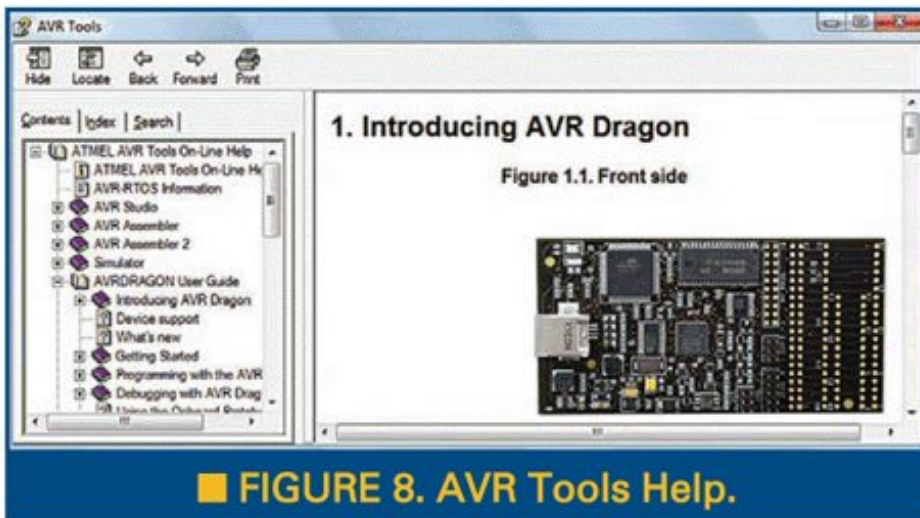
We will use the Dragon to put the bootloader on the

■ FIGURE 6. Dragon with jumpers.

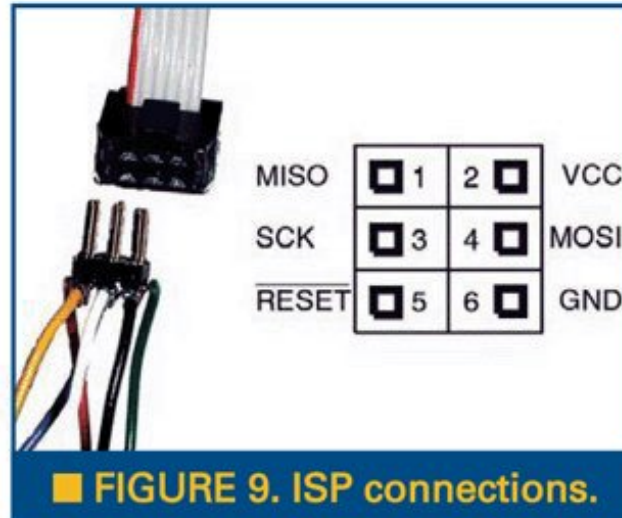


■ FIGURE 7. Ecrostech Dragon Rider.
(Photo used with permission of Graham Davies of Ecrostech).





■ FIGURE 8. AVR Tools Help.



■ FIGURE 9. ISP connections.



■ FIGURE 10. The Medusa ISP cable.

BeAVR then we will use that bootloader for future programming efforts. We are going to go the cheapo route and directly wire the Dragon ISP port to the BeAVR SPI port. [BTW, SPI is not a typo. The ISP (In System Programming) goes through the SPI (Serial Peripheral Interface).]

I happened to have a six-wire IDC cable lying around and a six-pin male header, so I chose the method shown. Before getting started on this, I suggest you open the AVRStudio Help\AVR Tools (Figure 8), find the section on the Dragon, and read it. I summarize some of the more relevant stuff for our venture. In Workshop 21, we were introduced to AVRStudio and WinAVR. You can get them at www.atmel.com/dyn/products/tools_card.asp?tool_id=2725 and <http://winavr.sourceforge.net/download.html>.

Medusa?

Talk about a bad hair day ... how would you like to have to comb out that curly top? Our Medusa isn't quite as bad, but let me tell you up front, it will get ugly before it gets pretty, and it might just turn you into stone in the process. You will need to solder six 4" AWG 22 solid core wires to the base of a 2 x 3 0.1" male header (without short-circuiting them – and that is a trick!) as shown in

Figure 9. Then, you will want to add "Scotch" tape (actually, any nationality tape will do) flags to each wire and mark them with the SPI signal names as shown in Figure 10. I suggest you get a multimeter and check continuity for each wire. Make sure it conforms to the signal as it starts at the Dragon, passes through the Medusa, then arrives at the BeAVR. Figure 11 shows the finished rat's nest. Let's be honest, I didn't wire this correctly the first time I tried, but eventually got it right. Cheap has a price.

Using AVRStudio to Upload the Bootloader

The AVRStudio Programming Front-End – as AVRStudio calls it –

allows you to use several hardware programmers, including the Dragon.

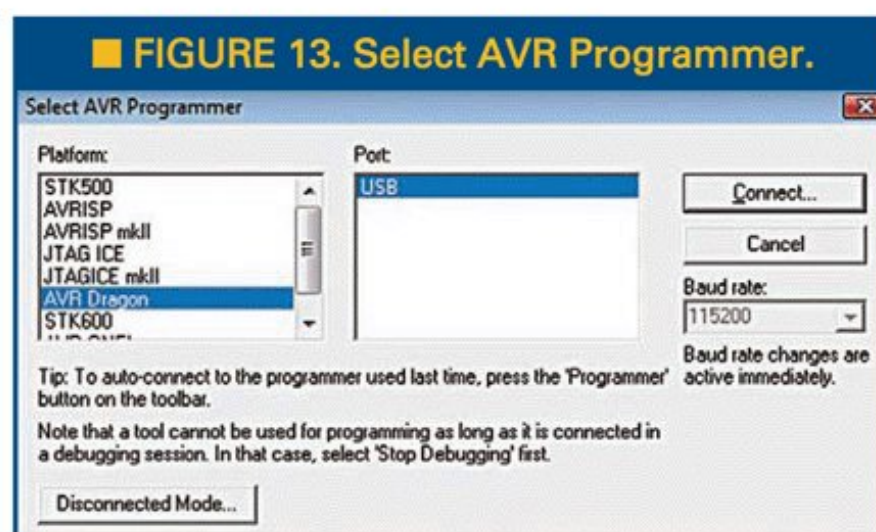
Let's do this cookbook style. Click on the 'Display the 'Connect' Dialog' as shown in Figure 12.

In the resulting 'Select AVR Programmer' window shown in Figure 13, highlight the AVR Dragon and USB.

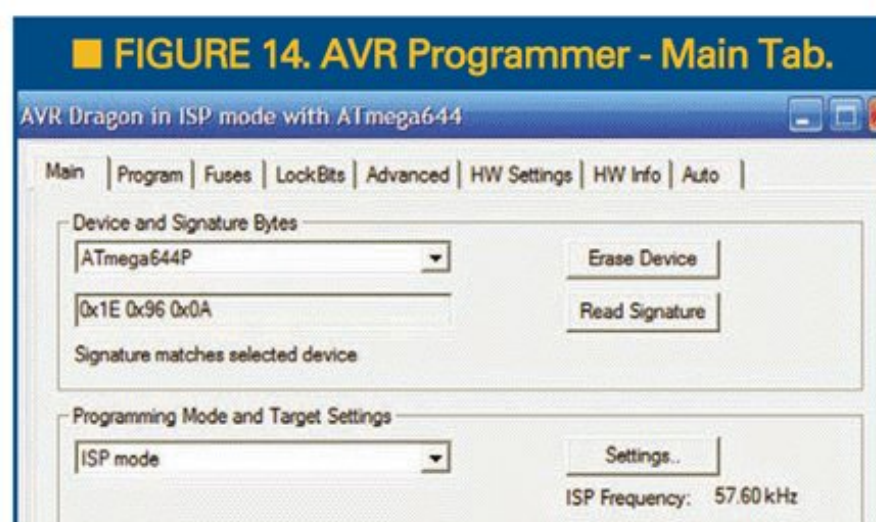
Open the 'Main' tab as shown in Figure 14 and push the 'Read Signature' button. If you see the three hex numbers shown in the window and it says 'Signature matches selected device', then you are in business. If not ... something's probably not right about your hardware setup.

Open the 'Fuse' tab as shown in Figure 15. Click the boxes and set the settings EXACTLY as shown in the picture. This is where you get the opportunity to turn your ATmega644 into a brick if you get it wrong. (Bricked AVR's can be unbricked with high voltage programming which is – as they say – 'a whole 'nuther topic.)

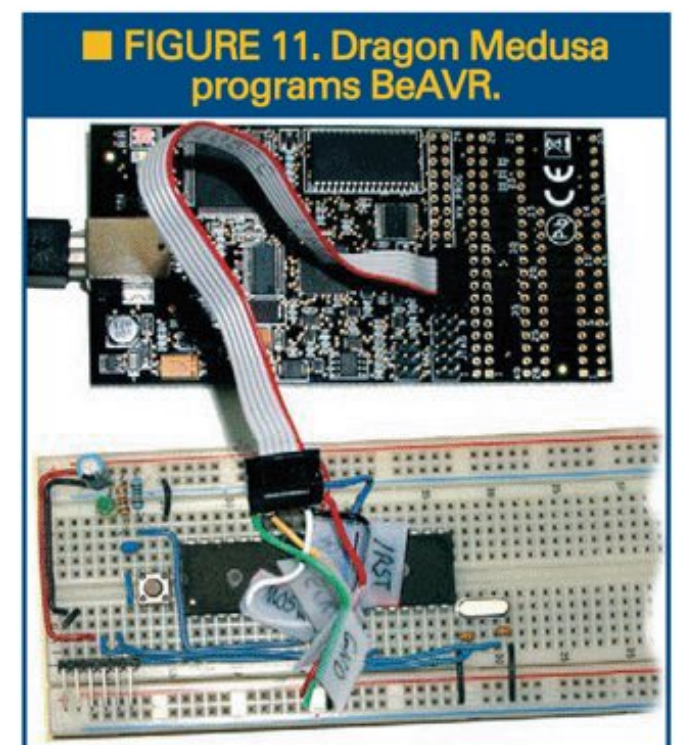
Finally, open the 'Program' tab as shown in Figure 16 and browse to find the input hex file (which should be the SmileyBootloader644. hex you got from the



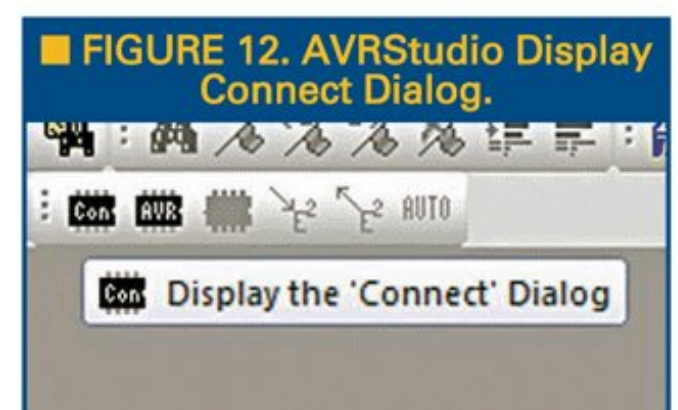
■ FIGURE 13. Select AVR Programmer.



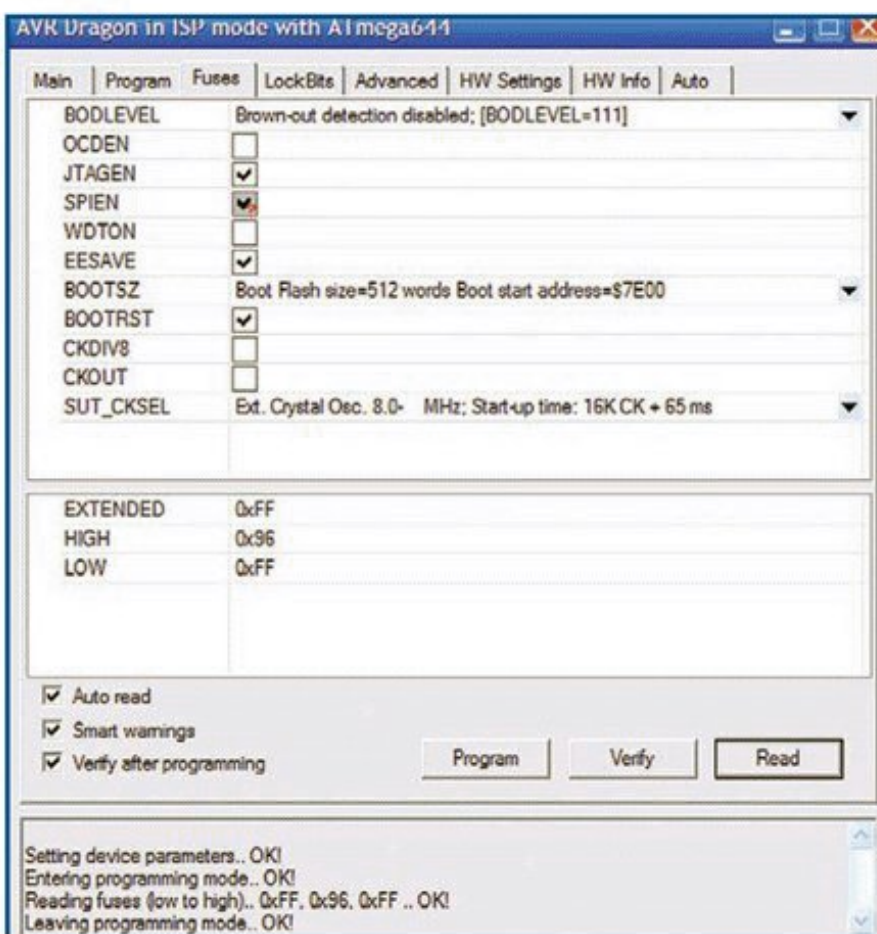
■ FIGURE 14. AVR Programmer - Main Tab.



■ FIGURE 11. Dragon Medusa programs BeAVR.



■ FIGURE 12. AVRStudio Display Connect Dialog.



■ FIGURE 15. AVR Programmer - Fuses Tab.



■ FIGURE 17. FTDI TTL-232R-5V USB-to-Serial cable.

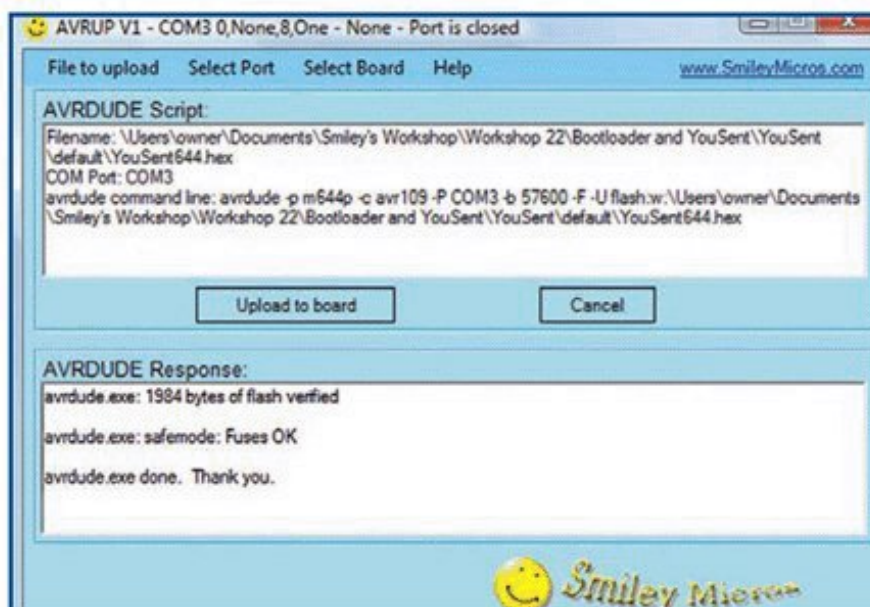
Workshop22.zip file). The text box at the bottom should tell you that you succeeded.

Talking BeAVR

Notice in **Figure 1** in the lower left corner there is a connector with six wires heading out of the photo. That device is the FTDI TTL-232R-5V USB to Serial cable that you can get from [www.ftdichip.com/Products/EvaluationKits/TTL-](http://www.ftdichip.com/Products/EvaluationKits/TTL-232R.htm)



■ FIGURE 16. AVR Programmer - Program Tab.



■ FIGURE 18. AVRUP-V1.

am working on an upgrade for AVRUP and may have further instructions for the BeAVR by the time you read this.

Using YouSent

Open the device in Simple Terminal (available from www.smileymicros.com) and send a character. The Receive box should show 'You sent: x' (where 'x' is the character you sent). Well, I told you how busy we'd be this month. Next month, we will continue with the BeAVR and introduce a version of the design for a PCB – and this BeAVR will have fangs! **NV**

232R.htm or from www.adafruit.com. Or, you can substitute the SparkFun FTDI Basic Breakout – 5V DEV-09115 (you will have to move a couple of wires on the breadboard for this one, so pay attention). Either of these options will allow you to talk to the BeAVR serial port using the PC USB. Our first use for this will be to upload YouSent.hex (located in Workshop22.zip) using AVRUP-V1 (**Figure 18**), as was discussed last month. Please check the www.smileymicros.com website because I

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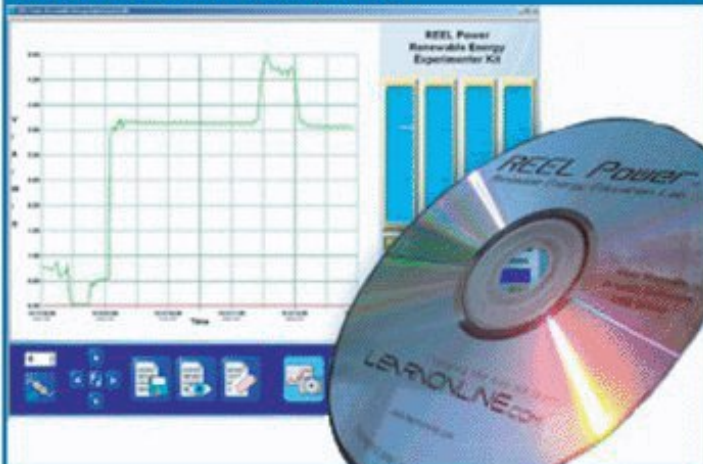
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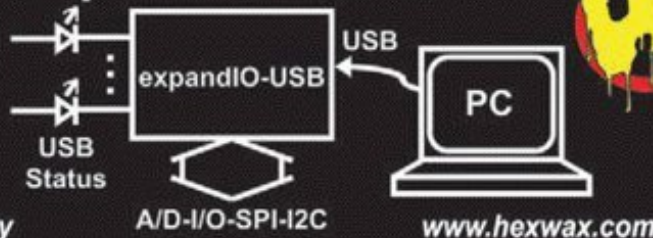
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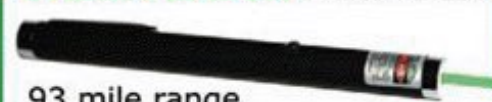


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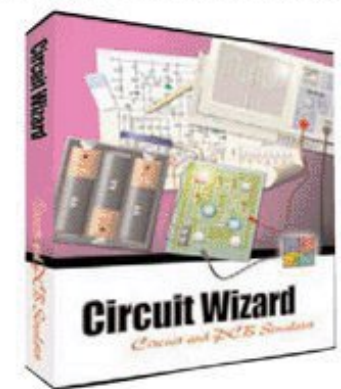
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generating signals up to 125 MHz with high sample rate, long memory, and high resolution, as well as a variety of operating modes, modulation capabilities, and a digital pattern generator. The software interface that controls the hardware is designed to simplify waveform creation with an intuitive navigation tree which allows easy access to all channels along with special views for controlling basic function generator outputs, as well as pulse width modulation (PWM) capabilities. The ability to have two and four channel units in a single, compact form factor can save bench space and help provide a lower price per channel. Additionally, the four channel ArbStudio models have an expansion port that allows up to eight units to be connected, providing up to 32 synchronous analog waveforms.

Four ArbStudio models are available, which offer a combination of analog waveform and digital pattern generation capabilities. All models have a bandwidth of 125 MHz, maximum sample rate of 1 GS/s, long memory of 2 Mpts/ch, and high 16-bit resolution.

The ArbStudio software runs on an external PC freeing the user from the small displays and readouts found on a typical AWG. A simple function generator window is available for basic waveform creation while a unique, streamlined control panel dedicated for PWM signals is also available. The main software mode features a start page that provides tutorials on creating a wide range of both simple and complex waveforms, as well as shortcuts to recent projects and an intuitive navigation tree to get started quickly. Once waveform creation has begun, graphical displays show the waveforms that have been created or sequenced, and the views can be customized to only show the windows that are of most interest to the user.

Arbitrary waveform generators are typically available with one of two technologies: either True Arbitrary or Direct Digital Synthesis (DDS). Each of these modes comes with advantages and disadvantages however, the ArbStudio does not have this limitation; it provides both modes and allows the user to choose which mode is needed for their waveforms. Additionally, ArbStudio channels can be set to any mode independently of each other for flexibility. The two channel ArbStudio 1102 price starts at \$2,490, with the entire product line ranging from \$2,490 to \$4,990.

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>>> QUESTIONS

Wireless Networkable Digital Picture Frame

I want to send digital pictures and/or video remotely to a digital picture frame located at my Grandma's house. The picture frame should have a wireless network ability so I can connect to it and update the video/picture content. What circuits or networking devices do this?

#5101 **Michael Jimenez**
Los Angeles, CA

Anti-theft Alarm

I would like to make a simple/inexpensive anti-theft alarm — like you see in the doorways of shops. Some form of oscillator circuit that is interrupted (disturbed) by a small passive antenna-like circuit passing through the field would be good.

The active range should be about 1-1.5 meters.

#5102 **Claes Kamborn**
Stockholm, SWEDEN

Load Controller, Micro Hydro

I built a 3,000W, 220V, micro hydro machine and installed it for a family of five living near a stream. I need a load controller to offset the extra power whenever something is turned off. When the real load goes down, the frequency and voltage go up. The design should monitor the frequency (50 Hz) and dump some load to resistors whenever the frequency starts going up, and dump less of that load when the frequency goes down. If there is a better idea please let me know. Is PWM a good option?

#5103 **Joseph K.**
La Jolla, CA

Alternator Output

It is my understanding that a standard automotive alternator produces three phase AC before the rectifier + (three diodes). If this is the case, what would the voltage and

amperage output of each phase be, as well as across two phases (tapped directly off the windings)? I would base measurements preferably using a 130 amp AC Delco CS130 alternator, but any info will help. At this point, I don't need any regulation, as I'm just trying to find out average values.

Also, what RPM would best suit the alternator for longevity, as well as best output (they don't put out full power until a set RPM minimum is reached)? Is there a set math formula to figure this out? At this time, I don't have access to the Internet.

#5104 **Geoffrey Mayberry**
a.k.a., "The Mad Scientist"

>>> ANSWERS

[#12098 - December 2009] Fuses

I have a machine that calls for a 3.15A 125V slow blow fuse. Will a 3.15A 250V slow blow fuse be wrong? I can't find a 125V SB fuse. Do they still make them?

You can use the 250V fuse.

To make it simple, fuses have three parameters: max current before it blows, rated in amps; response time (fast blow vs. slow blow); and voltage rating. The element inside the fuse will heat up as current increases through it, until it reaches its maximum rating. Then, it will literally melt or "burn open," stopping current flow — in your case, 3.15 amps. Your fuse being a slow blow type, the element has a built-in time delay to allow for current inrush when you first turn on the machine. Your machine may pull four or five amps for a few milliseconds

until it settles down to its normal operating current. If you had a quick blow fuse in place instead, it would blow most every time you turned on the machine — which would be a nuisance.

Voltage ratings on the fuse indicate the maximum voltage source the fuse will clear. Cartridge fuses are typically rated at 32, 125, 250, and 600 volts. When the element burns in two, there is a gap. If the fuse voltage rating is lower than the applied voltage, current may arc across the gap and continue to flow. Higher voltage fuses blow larger gaps in the element. So, if you used a 32 volt fuse in your 120 volt application, it may not clear and stop current flow when it blows. However, the 250 volt fuse will clear a large enough gap to interrupt the 120 volt circuit.

Finally, some small cartridge fuses have a glass body, others ceramic. In a lot of instances, they are interchangeable (assuming electrical ratings are the same). However, ceramic body fuses are intended for installations with higher heat and/or more mechanical vibration. It's best to replace the ceramic with ceramic, but if not available — and the need is great — you can get by on the glass until the proper replacement is found.

Occasionally, a fuse will fail without an electrical overcurrent being present. Heat or vibration can cause the element to open, sometimes under the endcaps where you can't see it. If the fuseholder has dirty or corroded contacts, they can generate enough heat to fail the fuse. If you keep blowing fuses and a bad fuseholder isn't present, there is probably a

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fault in your machine. NEVER NEVER substitute a higher ampere rated fuse! This is a fire/safety hazard!

Phil Shewmaker
Louisville, KY

[#1101 - January 2010] Stuttering Discs

I have CD and DVD players which, when playing certain discs, will stutter, skip, cut in and out, and sometimes abort the playing altogether. It only does it on some discs, and at the same place on these discs. However, these same discs will work on other players just fine. On at least one player, the problem got progressively worse, and had trouble with discs it played without errors in the past. Is there a way to repair this? Cleaning the lens and disc sometimes helps, but not always. I am playing only commercially made CDs and DVDs, not home burned ones.

It sounds as if you have either some sort of build-up, lack of lubrication due to hardened or missing lubricant, or a combination of the two. The reading assembly on CD and DVD players consists of a sled on guides (usually two rods) moved by a rack and pinion (or screw). This functions as the coarse movement. The fine tracking is done through a voice coil assembly on springs holding the laser and detector. A third movement in perpendicular direction takes care of the focus. Cleaning the rods, gears, and guides, as well as providing fresh lubricant will usually take care of these issues.

Be sure that there is no dust or lubricant in areas where it does not belong.

Walter Heissenberger
Hancock, NH

[#1102 - January 2010] Tunable Sine Wave Generator

I am working on a project to provide 100 inexpensive, disposable electronic devices for a church. Each device requires a cheap, low-distortion, parts-stingy sine wave generator, easily tunable using only one pot from 1 kHz to 1 MHz, preferably using one common and cheap IC like an op-amp or a few transistors. To be compact, the parts count should be under about a dozen. I have plenty of XR8038 and XR2206 function generator ICs, but they are far too costly for this project. My experiments have produced only square waves or triangular waves, but meet all my other criteria. What is the best sine wave design?

Simple oscillator circuits capable of 1,000:1 tuning range and exhibiting pure sine wave output with good amplitude stability probably do not exist. However, one of the following techniques should be acceptable in your application:

[1] Generate a square wave or pulse at a multiple of the intended output frequency, then convert to sine with a simple counter and resistor network. Don Lancaster discusses cheap digital sine wave generators at length in his *CMOS Cookbook* on pages 379~385 (second edition).

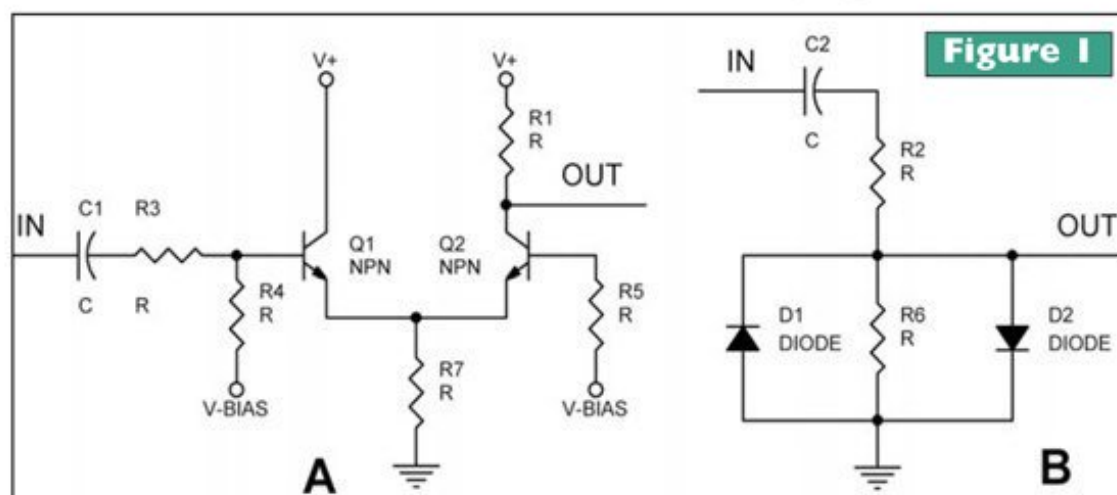
The primary disadvantage is high distortion when the oscillator frequency is a low multiple of output frequency.

[2] Use a tracking bandpass filter based on

switched-capacitor IC technology to convert square or triangle waves to sine. The oscillator runs at a high multiple — such as 64X or 128X — to clock the switched-capacitor filter chip. I suspect this technique is too costly for the intended application.

[3] Generate a triangle wave, then convert to sine by shaping it with a transistor differential amplifier or diode network. This technique is standard in function generators, and it's capable of 2% distortion or better if optimized. See **Figure 1** for additional details on a couple of circuit concepts. Your triangle wave must be attenuated to about 85 mVpp at the input base of the differential transistor pair (**A**). The actual value is critical for minimum distortion. Base bias resistors should be low and equal in value. Reduced emitter coupling can yield further improvement, but I suspect this refinement is unnecessary. The bone-head-simple diode network (**B**) might be entirely sufficient if resistor values are well selected. Output from that circuit will be about 1.2 Vpp with common silicon diodes. Try LEDs or multiple series diodes for higher output.

[4] Build a heterodyne generator with two nearly identical square wave oscillators running at a frequency much higher than your intended output, say 10 MHz. Make one of them variable from 10.001000 MHz to 11.000000 MHz. Combine both outputs in a non-linear mixer such as a logic gate, analog switch, or diodes. Mixer output includes sum and difference frequencies, but the sum is easily removable with an R/C low-pass filter. The remaining difference frequency is a beautiful sine wave! Unbalanced mixers also pass raw input signals to the output, but the LPF (or notch filter) solves this problem, as well. Beware the dreaded lockup phenomenon: The slightest stray coupling between two oscillators snaps them into synchronization when the variable one is tuned too



near the fixed one.

Mike Hardwick
Decade Engineering
Turner, OR

**[#1104 - January 2010]
Speaker Hum**

I have a problem with my speakers humming on my desktop PC. I think this may be wall wart related but not 100% sure.

Is there a way to fix this problem or do I need to buy a new set of speakers?

You could look at several areas to solve the speaker hum with your PC.

First, it could be a poorly filtered wall wart and you might want to replace it as the filtering that it has is just not enough to overcome hum in the system. You could also check/replace the cable that goes between the sound card in the PC and the speakers. Could be that the shield is cracked and this is where the hum is being introduced into the system. Also, try to use as short a cable as possible between the two as the longer the cable, the more likely it will act as an antenna picking up any electronic noise anywhere near the system. Try moving the speakers to another location a short distance away from the PC and see if that improves the sound quality. If the sound card is external to the motherboard, try removing and reseating it as there may be some contact issues between the card and the motherboard slot that the card plugs into. Lastly, trash the speakers you have and go with a better quality speaker system. You did

not indicate what brand they were. If they are the no-name generics, they would be more prone to external noise.

Ralph J. Kurtz
Old Forge, PA

**[#1105 - January 2010]
Automotive Speed Sensor**

I recently replaced the trans in my Ford van. Somewhere between 00 and 02 model years, Ford changed the speed sensor output to the PCM, but I have an analog gear driven sensor. The newer sensor is digital (variable reluctance). I need to change the signal back to analog so the speedometer, ABS, and cruise will work. Is there a device to do it, or is it even possible?

All you need is a Frequency-to-Voltage (F/V) converter with a Schmitt-trigger input. There are many published circuits available to pick from. **Figure 2** shows an adaptation of a National Semiconductor circuit (AN-140). A comparator was used – instead of the CMOS-Schmitt inverter – to obtain better control of the input switching thresholds. R1 and R2 adjust the level, and R3 the hysteresis. A clean 50% square wave must be at the output of U1, swinging almost rail-to-rail (if necessary adjust R1, R2, and R3). Current flows on a negative output swing from the inverting node through D1 and C1. The current is only a function of the frequency and size of C1, since the output swing of U1 is fairly constant. C2 and R6 provide a voltage output. There are many different variants of this circuit

(see the National Semiconductor and Linear Technology sites), giving further insights on capacitor selection and much more. Alternatives are the LM331 ($\pm 0.06\%$ non-linearity); Linear Technology has some precision circuits going into the PPM region.

Walter Heissenberger
Hancock, NH

**[#1106 - January 2010]
Design/Test Software**

I've had electronic engineering schooling back in the '80s and have tinkered a little since then. I've never had a computer until now and would like to know some free or reasonable circuit design/test software download sites to tinker with.

Circuit Simulators: LTspice IV (free, no limitations, excellent; Linear Technology) and Tina-TI (free scaled-down version; Texas Instruments).

CAD/Layout: ExpressPCB (free) and ExpressSCH (free) are PCB layout and schematic software. Very consistent and easy to use. QuickCAD mechanical CAD software is from Autodesk.

Miscellaneous: AppCAD (free; Agilent) calculates transmission lines, S-parameters, microwave designs, amplifiers, biasing, reflections, noise, etc. MPLAB (free; Microchip Technology, but needs a plug-in for C or MBasic, and a programmer) software is used to program PIC microcontrollers. There's Microsoft Office which includes Word, Excel, PowerPoint, and Access for general office type applications such as

documents, spreadsheets, presentations, and databases. FilterPro (free, Texas Instruments) software is used to design active filters. Last but not least is SpectrumLab (free; uses sound card to digitize and analyze spectrum).

Walter Heissenberger
Hancock, NH

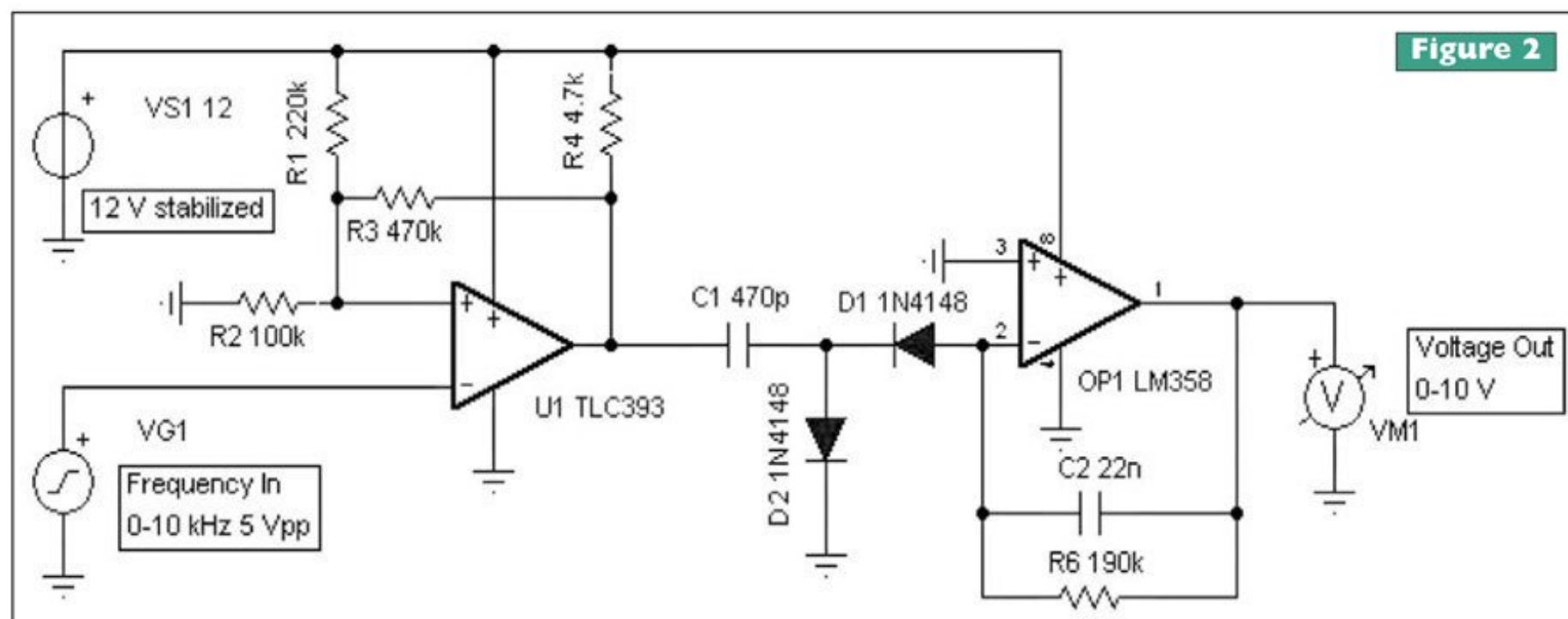
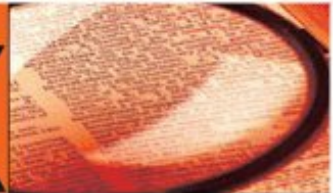


Figure 2



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2.4GHz 2 Camera Wireless System



- * Channel-scan for multi-camera monitoring
- * Night vision (Effective range: 7m)
- * Shell, Weather-proof structure for outdoor installation
- * Built-in microphones for audio monitoring
- * Up to 100m (330ft.) range in open space
- * Includes 2 cameras w/power supplies & 1 receiver w/power supply and remote control



Item #

DUAL CAM SYSTEM

\$98.50

LED Flashlight with On Board 4GB DVR



Ideal for:
Law Enforcement,
Post Fire Inspection,
Facilities
Maintenance,
Security Companies,
& Many Other Uses!

Monitoring & Recording concealed in a rechargeable flashlight

This unit will function both as a flashlight AND a Digital Video Recorder and has a multitude of uses. It is equipped with a convenient USB interface for video data file transfer. You can record color video and then transfer it to a personal computer for viewing. Includes two light levels for close up or long distance recording. Also includes a AC adapter for charging the internal Li battery.

Item #

FLASHLIGHT DVR

SALE

\$69.00

Regular Price
\$189.00!

Ideal for Law Enforcement,
Post Fire Inspection, Plumbing,
Facilities Maintenance,
Security Companies, & Many
Other Uses!



Aardvark II Dual Camera

Wireless Inspection Camera

With Color 3.5" LCD Recordable Monitor

Your Extended Eyes & Hands!

RECORDS
Still Pictures
& Video

See It!

Clearly in narrow spots,
even in total darkness or
underwater.

Find It!

Fast. No more struggling
with a mirror & flash light.

Solve It!

Easily, speed up the solution
with extended accessories.

Record It!

With the 3.5" LCD recordable
monitor, you can capture
pictures or record video for
documentation.

Full specifications at

www.CircuitSpecialists.com/Aardvark

The Aardvark Wireless Inspection Camera is the only dual camera video borescope on the market today. With both a 17mm camera head that includes three attachable accessories and a 9mm camera head for tighter locations. Both cameras are mounted on 3ft flexible shafts. The flexible shaft makes the Aardvark great for inspecting hard to reach or confined areas like sink drains, AC Vents, engine compartments or anywhere space is limited. The Aardvark II comes with with a 3.5 inch color LCD monitor. The monitor is wireless and may be separated from the main unit for ease of operation. Still pictures or video can also be recorded and stored on a 2GB MicroSD card (included). The Aardvark's monitor also has connections for composite video output for a larger monitor/recorder and USB interface for computer connection. Also included is an AC adapter/charger, video cable and USB cable. Optional 3 ft flexible extensions are available to extend the Aardvark's reach (Up to 5 may be added for a total reach of 18 feet!).



Item #

AARDVARK

\$249.00

3ft Extension **AARDVARK-EXT \$24.95**

USB Digital Storage Oscilloscopes

Probes
Included



- * High performance:
- * USB connected: Uses USB and supports plug'n play, with 12Mbps communication speed.
- * Best performance for your dollar: These units have many features that are comparable to the high speed stand-alone DSOs. But costs a fraction of the price.
- * No external power required: Bus-powered from the host computers USB port.
- * Probes & USB cable included.
- * Easy to use: Intuitive and easy to understand.
- * Various data formats: Can save waveform in the following formats: .txt .jpg .bmp & MS excel/word

40MHz **DSO-2090** **\$169.00**

60MHz **DSO-2150** **\$194.00**

200MHz **DSO-5200** **\$289.00**

Specifications	DSO-2090	DSO-2150	DSO-5200
Channels		2 Channels	
Impedance		1M 25pF	
Coupling		AC/DC/GND	
Vertical resolution		8 Bit	9 Bit
Gain Range	10mV-5V, 9 Steps		10mV-10V, 10Steps
DC Accuracy		+/- 3%	
Timebase Range	4ns - 1h 38 Steps		2ns-1h, 39 Steps
Vertical adjustable		Yes	
Input protection		Diode clamping	
X-Y		Yes	
Autoset	Yes (30Hz~40MHz)	Yes (30Hz to 60MHz)	Yes (30Hz to 200MHz)
EXT. input		Yes	
Trigger Mode		Auto / Normal / Single	
Trigger Slope		+/-	
Trigger Level Adj.		Yes	
Trigger Type		Rising edge / Falling Edge	
Trigger Source		Ch1 / Ch2 / EXT	
Pre/Post trigger		0-100%	
Buffer size	10K-32K per ch		10K-512KB per ch
Shot Bandwidth	DC to 40MHz	DC to 60MHz	100MHz
Max Sample Rate	100MS/s	150MS/s	250MS/s
Sampling Selection		Yes	
Waveform Display		port/line, waveform average, persistence, intensity	
Network		open / close	
Vertical Mode		Ch1, Ch2, Dual, Add	
Cursor Measurement		Yes	
		Spectrum Analyzer	
Channels		2 Channels	
Math		FFT, addition, subtraction, multiplication, division.	
Bandwidth	40 MHz	60 MHz	200 MHz
Cursor		Frequency, Voltage	
Data Samples	10K-32K/Ch		10K-1M/Ch

60MHz Hand Held Scopemeter with Oscilloscope & DMM Functions

Who Says

you can't take it with you?

With the **DSO1060** YOU CAN!



- 60MHz Handheld Digital Scopemeter with integrated Digital Multimeter Support
- 60MHz Bandwidth with 2 Channels
- 150MSa/s Real-Time Sampling Rate
- 50Gsa/s Equivalent-Time Sampling Rate
- 6,000-Count DMM resolution with AC/DC at 600V/800V, 10A
- Large 5.7 inch TFT Color LCD Display
- USB Host/Device 2.0 full-speed interface connectivity
- Multi Language Support
- Battery Power Operation (Installed)

Item #

DSO1060



\$569.00

Your Power Supply Headquarters!!

We carry a LARGE selection of power supplies from bench top to variacs to single, dual and triple output to wall plug AC adapters to large and ultra large regulated power supplies.

Adjustable DC Power Supplies with Adjustable Current Limiting



Regulated linear power supplies with adjustable current limiting. The LED display shows both Volts & Amps. The current output can be preset by the user via a front panel screwdriver adjustment screw while the voltage is adjustable by a front panel multi-turn knob for precise voltage settings. Output is by front panel banana jacks and there is also a covered terminal strip for remote voltmeter sensing at the load.

- * Utilizes SMD technology
- * Pre-Settable Voltage & Current levels
- * Front Panel On/Off Switch
- * Large LED readout for Voltage & Current
- * S+ & S- Sampling terminals

0-30 Volt / 0-10 Amp Adj.	(CSI3010X)	\$198.00
0-30 Volt / 0-20 Amp Adj.	(CSI3020X)	\$299.00
0-40 Volt / 0-10 Amp Adj.	(CSI4010X)	\$269.00
0-60 Volt / 0-10 Amp Adj.	(CSI6010X)	\$319.00
0-120 Volt / 0-3 Amp Adj.	(CSI12003X)	\$265.95

www.circuitspecialists.com/dcpower

Programmable DC Electronic Loads



These devices can be used with supplies up to 360VDC and 30A. It features a rotary selection switch and a numeric keypad used to input the maximum voltage, current and power settings. These electronic DC loads are perfect for use in laboratory environments and schools, or for testing DC power supplies or high-capacity batteries. It also features memory, and can also be connected to a PC, to implement remote control and supervision.

360V/150W (CSI3710A) \$349.00

www.circuitspecialists.com/csi3710a

360V/300W (CSI3711A) \$499.00

www.circuitspecialists.com/csi3711a

HengFu Switching Power Supplies



Circuit Specialists carries a wide selection of HengFu switching power supplies. All models have overload, over voltage, over temperature & short circuit protection.

Hi-Power Enclosed Single Output

	Item #	1+	10+
1000W 12v/84A	(HF1000W-SM-12)	\$299.00	
1000W 24v/42A	(HF1000W-SM-24)	\$299.00	
700W 48V/15A	(HF700W-S-48)	\$189.00	\$174.00
500W 48V/11A	(HF500W-S-48)	\$119.00	
500W 24V/21A	(HF500W-S-24)	\$169.00	\$149.00
500W 12V/42A	(HF500W-S-12)	\$169.00	\$149.00
300W 48V/6.3A	(HF300W-S-48)	\$69.00	\$61.00
300W 36V/8.5A	(HF300W-S-36)	\$69.00	\$61.00
300W 24V/12.5A	(HF300W-S-24)	\$69.00	\$61.00
300W 12V/25A	(HF300W-S-12)	\$69.00	\$61.00
300W 9V/33A	(HF300W-S-9)	\$69.00	\$61.00
300W 5V/60A	(HF300W-S-5)	\$69.00	\$61.00

Open Frame Single Output

	Item #	1+	10+
15W 5V/3A	(HF15W-SPL-5)	\$15.99	\$13.59
15W 12V/1.3A	(HF15W-SPL-12)	\$15.99	\$13.59
15W 24V/0.85A	(HF15W-SPL-24)	\$15.99	\$13.59
15W 48V/0.32A	(HF15W-SPL-48)	\$15.99	\$13.59

Enclosed Dual Output

	Item #	1+	10+
5V/10A-12V/4A	(HF100W-DF-A)	\$39.00	\$34.88
5V/15A-15V/2A	(HF100W-DF-B)	\$39.00	\$34.88
5V/24A-24V/1A	(HF100W-DF-V)	\$39.00	\$34.88
5V/1A-5V1.8A	(HF10W-DL-A)	\$15.95	\$13.79
5V/1.8A-12V/0.5A	(HF10W-DL-B)	\$15.95	\$13.79
5V/1.8A-15V/0.5A	(HF10W-DL-C)	\$15.95	\$13.79
5V/1.8A-24V/0.3A	(HF10W-FL-D)	\$15.95	\$13.79

www.circuitspecialists.com/hengfu

POTRANS [Special Purchase]

150Watt 24V/6.5A Switchable Power Supply

- * High efficiency
- * High reliability
- * Protection: Over-voltage/Over-current/Over-power/Short-circuit
- * Output reverse protection
- * VAC input range selected by switch
- * 100% full load burn-in test
- * EMI/RFI: FCC Part 15J, Class A & CISPR 22 Class A



Item # CSI-15024-1M

1+\$19.00 10+\$14.95 100+\$12.95

UL, cUL, CCC, CE & TUV approved

Programmable DC Power Supplies

- * Up to 10 settings stored in memory
- * Optional RS-232, USB, RS-485 adapters
- * May be used in series or parallel modes with additional supplies.
- * Low output ripple & noise
- * LCD display with backlight
- * High resolution at 1mV



Model	CSI3644A	CSI3645A	CSI3646A
DC Voltage	0-18V	0-36V	0-72V
DC Current	5A	3A	1.5A
Power (max)	90W	108W	108W
Price	\$199.00	\$199.00	\$199.00

Dual Output DC Bench Power Supplies

High stability digital read-out bench power supplies featuring constant voltage & current outputs. Short-circuit & current limiting protection is provided. SMT PC boards and a built-in cooling fan help ensure reliable performance & long life. All 3 Models have a 1A/5VDC Fixed Output on the rear panel.



Item #:	Price 1+	Price 5+
CSI3003X-5 0-30V/0-3A	\$119.00	\$112.00
CSI5003X5 0-50V/0-3A	\$127.00	\$119.00
CSI3005X5 0-30V/0-5A	\$129.00	\$122.00

Triple Output DC Bench Power Supplies

- * Output: 0-30VDC x 2 @ 3 or 5 Amps & 1 fixed output @ 5VDC@3A
- * Stepped Current: 30mA +/- 1mA



Item #:	Price 1+	Price 5+
CSI3003X3 0-30Vx2@3A	\$198.00	\$193.00
CSI3005XIII 0-30Vx2@5A	\$259.00	\$244.00

0-30V / 0-5A . DC Power Supply



The CSI530S is a regulated DC power supply which you can adjust the current and the voltage continuously. An LED display is used to show the current and voltage values. The output terminals are safe 4mm banana jacks. This power supply can be used in electronic circuits such as operational amplifiers, digital logic circuits and so on. Users include researchers, technicians, teachers and electronics enthusiasts. A 3 1/2 digit LED is used to display the voltage and current values.

www.circuitspecialists.com/csi530s

Item #

CSI530S

\$79.00

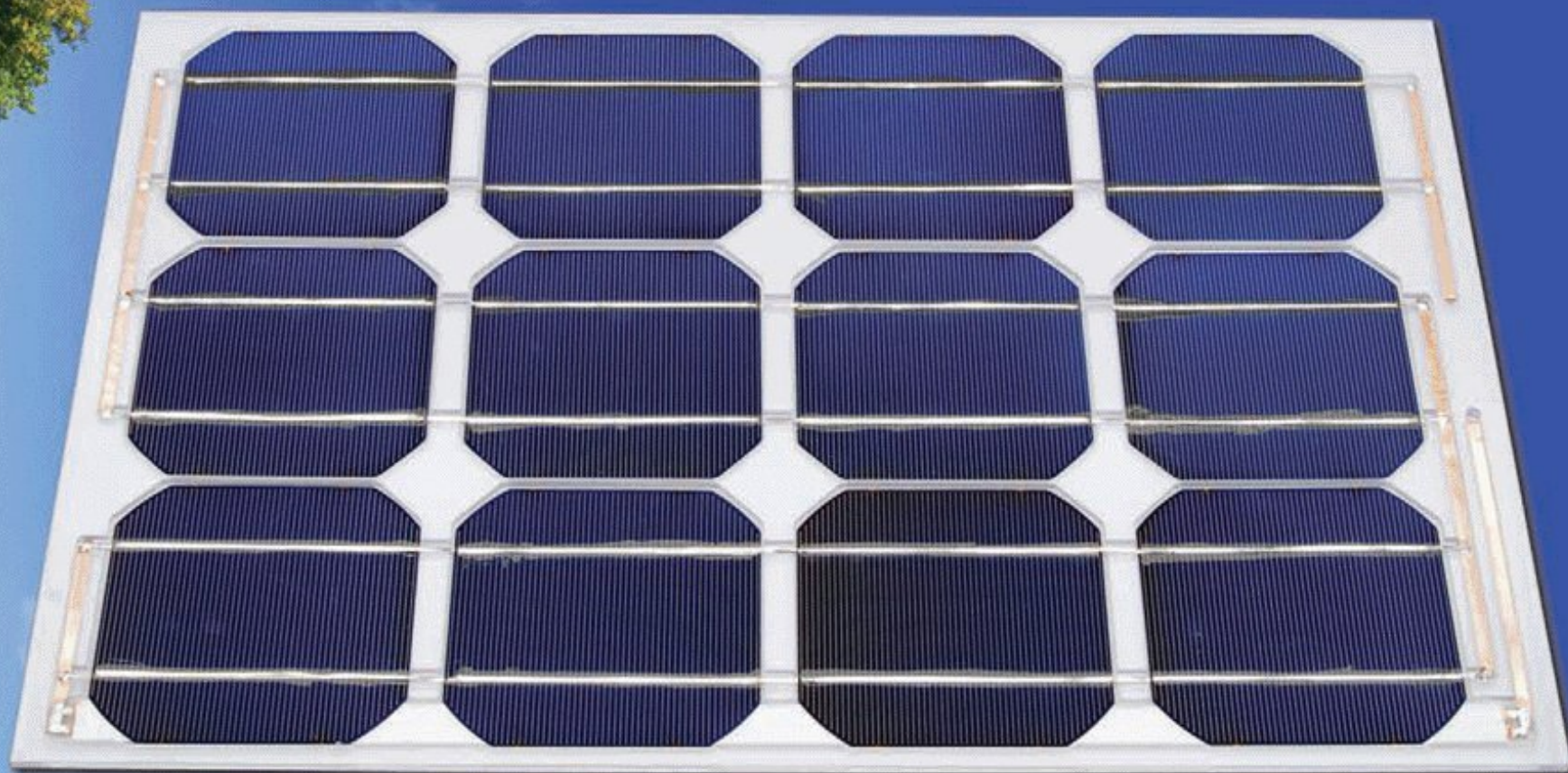
The Boss say's we gotta "Reduce inventory!"



Check out the special deals on our great selection of top quality BlackJack SolderWerks equipment

www.CircuitSpecialists.com/BlackJack

30 Watt Solar Panel Kit



Ready to get off the grid? Parallax's 30 Watt Solar Panel Kit is a do-it-yourself system that can produce up to a maximum of 30 watts of clean, green electrical energy. Not a solar demonstration toy! It is a true kit, once assembled you will have a solar panel that produces a substantial amount (6 volts) of electrical power. In fact, the energy produced per square foot is comparable to many commercially available solar panels. Once you permanently seal the panel, it can withstand the outside elements as well. Daisy-chain multiple units together for higher voltage/current/power output! Dimensions: 23.8 x 15.8 x 0.375 in (60.45 x 40.12 x 0.95 cm). Assemble your panel with confidence! Online demonstration videos show you how to properly handle and solder the delicate cells and their wiring interconnections.



30 Watt Solar Panel Kit
(#33000; \$149.99)

Order the **30 Watt Solar Panel Kit** at www.parallax.com or call our Sales Department toll-free: 888-512-1024 (Mon- Fri, 7am-5pm, PDT).

Friendly microcontrollers, legendary resources.™

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